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C O N T E N T S

DRILLING AND PRODUCTION

Page

Chains and Golf Balls Play Part in "Killing" Wild Gas Well 23
By K. C. SCLATER

Electric Equipment on Rotary Drilling Rigs 33
By G. R. PROUT

Deepening and Completing a Well in the Lisbon Field, Louisiana—A Study in Modern Coöperative Practice (Part 4) 103
By PAUL D. TORREY *and* FRANK H. MILLER

Removal of Drilling Mud From Formation By Use of Acid 117
By STANLEY C. MORIAN

Drilling and Completion Practices in Illinois Basin Involving Use of Lightweight Alloy Metal 121
By RALPH C. GRAHAM

REFINING AND NATURAL GASOLINE MANUFACTURE

The Compressibility of Gases (Part 5) 25
By GEORGE GRANGER BROWN

The Technology of Refining Processes (Part 5) 29
By ARCH L. FOSTER

Operating Data on Gas-Engine-Driven Compressors in East Texas Gasoline Plant 84
By H. H. BEESON

Synthesis of Petroleum-Like Hydrocarbons from Carbonaceous Material 95
By RAFAEL FUSSTEIG

New Dehydration-Refrigeration Plants Involve Use of Diethylene Glycol 113
By H. LEE FLOOD

OIL AND GAS TRANSPORTATION

Piping and Header Design to Minimize Pressure Drop 44
By C. S. WORLEY *and* D. K. HUTCHCRAFT

Laws of Fluid Flow in Rough Pipes (Part 2) 75
By J. NIKURADSE

GENERAL

Record Attendance Marks Nineteenth Annual Meeting of Natural Gasoline Association of America 50

International Petroleum Exposition Has Colorful Opening 52

Program—A.P.I. Tenth Annual Mid-Year Meeting 126

ENGINEERING NEWS OF INTEREST

A New Magnetic Method for Orienting Deflecting Tools 48

REGULAR FEATURES

	PAGE		PAGE
The Course of Oil	10	Running Tour With Men in the Industry	131 and 132
Highlights in Oildom	12	Laugh With Barney	136
Activities in Refining	14	Machinery and Equipment	138, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, and 150
Activities in the Oil Fields	16	Trade Literature	155
Petroleum Statistics and Field Activities	18	Book Reviews	160
Major Pipe Line Activities	20	Meetings	161
The Petroleum Engineer's Continuous Tables (Installment 35)	59		

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The Course of Oil

By K. C. SCLATER

International Petroleum Exposition Probably no single industry can boast of a pageant of progress such as that which the International Petroleum Exposition at Tulsa, Oklahoma, exemplifies. Here are concentrated the foremost developments in equipment and methods in every phase of oil production, refining, and transportation. Within a space of twenty-five acres there is on display ten million dollars worth of equipment, representing the products of more than six hundred exhibitors. This year, the Exposition surpasses all others in the number and variety of exhibits.

Despite the war now going on in Europe, delegates from some twenty-two nations are expected to visit the Exposition. Only eighteen nations were represented at the last International Petroleum Exposition, held two years ago. This gives one an idea of the growing international importance of petroleum. A new building has been constructed for the convenience of these foreign delegates, and special provisions are being made this year for making their visit to the Exposition pleasant and profitable.

Science continues to play an increasingly important role in the petroleum industry. Evidence of this is the fact that the Exposition's Hall of Science has been enlarged this year to accommodate overflow exhibits. An important addition is a motion picture projection room. One can obtain a complete cross-section of the latest developments in any branch of the petroleum industry.

The exhibits run all the way from machinery of the very heaviest type weighing many tons to the most tiny instruments of the utmost precision, and all displayed to the greatest advantage of the visitor.

For the men in the industry, the Exposition provides an intensive education. There is no phase of oil operations on which the latest information on equipment and processes cannot be learned.

Petroleum's Record of Achievement "The American Oil Industry may be fairly considered as one whose origin is strictly American; whose development to its present position of importance, both nationally and internationally, is unquestionably due to private initiative, enterprise, and capital in a free competitive economic system; whose achievements, wholly without benefit of public subsidy, have been of incalculable public benefit and service; and whose future contributions to the general welfare will be immeasurably great if collectivism and Federal control, under the false label of national planning, are not imposed upon this great industry in substitution for our system of free competitive enterprise.

"The accelerated pace of the petroleum industry's advance along technologic, economic and social lines is such that constant, periodic re-examinations are necessary, even for those engaged in the industry, to comprehend the significance of its broad general advance."

"In 1915, the United States Geological Survey estimated oil reserves of seven and one-half billion barrels in all known and possible oil bearing acreage by whatever method produced, but since that estimate, over nineteen billion barrels have been actually produced, and the latest estimate of proven oil reserves, as of January 1, 1940, is approximately eighteen and one-half billions of barrels of oil. In 1925 the American Petroleum Institute estimate of proven oil reserves recoverable by flowing and pumping methods then in use, was five billion barrels, and yet fourteen and one-half billion barrels have been produced since that date, with proven recoverable reserves of eighteen and one-half billion barrels as the current estimate.

"This almost unbelievable achievement could only have been accomplished by the ever increasing improvement in petroleum technology and the associated sciences and the great advances made in the field of geophysics and in the art of exploration and discovery. In November, 1922, the deepest producing well in the world was in the Orange field of Texas, at a total depth of 5,490 feet, while today in Kern County, California, a well drilled to a total depth of 15,004 feet, is now producing at a depth of 13,175 feet. The implications arising from this accomplishment are obvious."

Thus were some of the accomplishments of the American Oil Industry outlined by George A. Hill, Jr., President of the Houston Oil Company, Houston, Texas, before the Round Table Conference of the Chamber of Commerce of the United States recently in Washington. One wonders whether the industry could continue to maintain such a record of accomplishment under Federal control.

Filing Petroleum Literature Petroleum industry technique is in a constant state of change. New methods and equipment are continually being devised. Keeping up with these new developments is no easy task. Literature pertaining to the petroleum industry is now voluminous, and the man who wishes to keep abreast of the times has a job on his hands if he desires to arrange it for convenient and ready reference to suit his own needs. His is a difficult task.

Realizing this, *The Petroleum Engineer* for more than two years has been publishing a decimal classification for petroleum engineering literature. This classification has been prepared by Professor Uren, who himself has used it with much success over a period of many years. As a further service to its readers, *The Petroleum Engineer* for several years has carried an index number on all its feature articles. The articles are numbered according to the Uren Decimal Classification. The complete classification comprises a decimal index, and an alphabetical subject index for the convenience of those who are not familiar with the filing system.

A booklet containing the complete Uren Decimal Classification has been prepared at the request of many of our readers who have adopted the Uren classification for their own needs. It is hoped to keep the classication up-to-date by expanding it from time to time as occasion demands.

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« « HIGHLIGHTS IN OILDOM » »

Adherence to Bureau of Mines Production Estimate Imperative During Coming Months

The importance of maintaining close control over the volume of crude oil produced during the coming summer months has been stressed in recent statements by E. O. Thompson, member of the Texas Railroad Commission.

If the oil industry will hold production for the rest of the peak consuming season—June, July, and August—to the U. S. Bureau of Mines estimates of consumer demands, it is even possible that a price increase of approximately 15 cents per bbl. may be expected, according to Thompson. This increase would, however, merely compensate partly for the price cut of 25 cents more than a year ago when the price of East Texas crude oil was reduced from $1.35 to $1.10 per bbl.

In an earlier statement, Thompson further stressed the need for production control when he warned that another production shutdown similar to the one of last August might become necessary unless production is curtailed.

●

Right of Arkansas Commission to Halt Production in an Emergency Upheld by Supreme Court

The supreme court in a unanimous decision recently upheld the authority of the Arkansas oil and gas commission to halt production in the state's regulated oil fields in emergencies without a hearing. The opinion by Associate Justice E. L. McHaney stated that whether an emergency existed was for the commission and not the courts to decide unless fraud was shown.

The opinion, affirming the union chancery court, made no reference to the contention that the order, issued last August 17, as a part of the concerted action of other Mid-Continent oil-producing states, was for price-fixing purposes and not for the prevention of waste.

●

U. S. Chamber of Commerce Reviews Problems Besetting Petroleum Industry

The importance of the petroleum industry in the pattern of the industrial and commercial life of the entire nation is emphasized by the discussion of problems confronting the industry, particularly the possibility of federal control, that featured the annual meeting of the Chamber of Commerce of the United States, held recently in Washington, D. C.

Col. T. H. Barton, El Dorado, Arkansas, presented the outlook in the Southwest and challenged the government's efforts to saddle the industry with federal regulation and also condemned the excessive tax burden placed on the industry by federal, state, and local governments.

In a round-table discussion, the pros and cons of the Cole bill were argued by George A. Hill, Jr., Houston, Texas, and Dr. Ralph J. Watkins, economic adviser to the National Resources Planning Board.

In a round-table discussion, the pros and cons of the Cole bill were argued by George A. Hill, Jr., Houston, Texas, and Dr. Ralph J. Watkins, economic adviser to the National Resources Planning Board.

Watkins, however, avoided discussion of the Cole bill and stated that he appeared in his personal capacity rather than as a representative of the board.

"It is not my purpose to build a case for federal regulation in all cases, nor for exclusive federal regulation in any case," Watkins said. "I do contend that the Federal Government—as the only agency representative of all of us—must assure itself that the objective of conservation of these energy resources is being attained, and I contend further that parts of that task can be accomplished only by that agency of government which has jurisdiction over our entire domain, namely, the Federal Government. To make these contentions is not to say that these industries themselves do not have vital roles to play in the fight for conservation, and not to say that the governments of the producing states do not have vital roles to play."

●

East Texas Proration Case Moves to Supreme Court

Oral argument has been concluded before the U. S. Supreme Court in the Rowan and Nichols Oil Company case, the first of the suits attacking proration orders of the Texas Railroad Commission in the East Texas field to be reviewed by the higher court.

The case involves production from five wells on a lease owned by Rowen and Nichols and in another suit the company has instituted a similar case involving seven wells on another lease. Humble Oil and Refining Company has also brought suit on similar grounds.

In the arguments, the company attacked the commission's order that prorated allowable production to each well in the ratio of 2.32 percent of the average hourly potential. Counsel suggested to the court that the question might be moot, since the commission had changed its allocation formula since the suit was instituted, and that the question at issue in the litigation is not at this time the rule of the Texas commission. This point was not argued by counsel, but the court directed numerous queries in an effort to determine if the issue involved, is, in fact, moot.

●

Natural Gas As Chemical Raw Material

The importance of natural gas as a raw material for the chemical industry was emphasized forcefully in a recent talk by C. George Segeler, engineer of utilization, American Gas Association, before the Industrial Gas Sales Conference at Toledo, Ohio.

"The total annual volume of gas used in chemical processing is almost equal to the total sales of natural gas for domestic purposes as shown in our annual A.G.A. statistics (about 350,000,000,000 cu. ft.). It appears impossible that such a quantity of gas should have been sold for chemical purposes while the gas industry hardly knows about it. Yet this is true although a substantial portion has gone into the making of carbon black in which the gas industry takes no pride because of its wasteful features. Still, it may be stimulating to realize that there is a real chemical market for gas and that here and there, one of the many applications may fit any gas territory."

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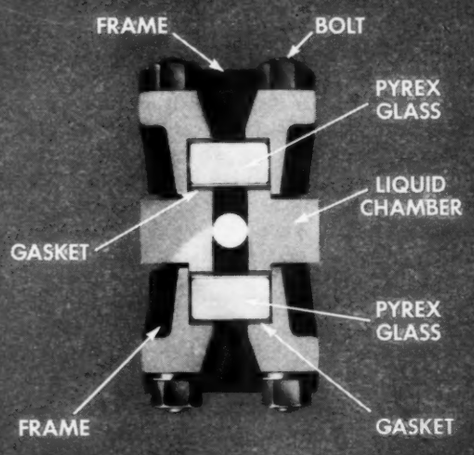

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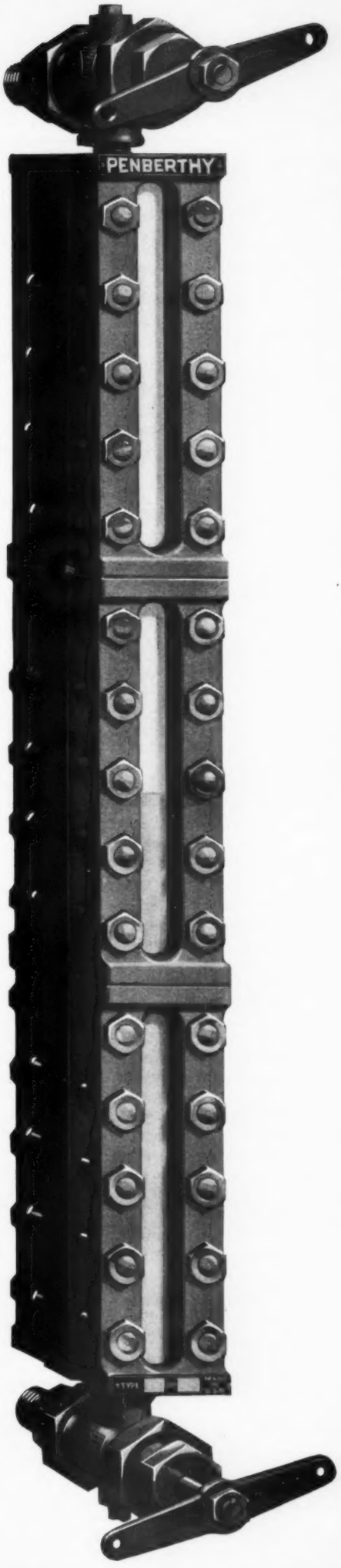

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PENBERTHY PRODUCTS

CANADIAN PLANT:
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Activities in Refining

Percent Refining Capacity Operated

Western Division, 61.2 Percent **Central Division, 79.5** **Eastern Division, 88.0 Percent**

THE NEW gasoline plant built by El Paso Natural Gas Company in southern Lea County, New Mexico, was recently placed in operation. The 75,000,000 cu. ft. per day plant is connected to more than 400 wells in the surrounding producing districts and represents one of the largest plants to be built in the general area. The entire gasoline output of the plant has been contracted by Phillips Petroleum Company.

●

A 500-bbl. refinery owned by The Sweet Grass Oil and Refining Company is nearing completion and will soon be placed in operation. The plant, situated at Coutts, northern Montana, will be supplied with crude oil produced in the Cut Bank field, to be delivered through the pipe line owned and operated by the Toronto Pipe Line Company.

●

Aurora Gasoline Company, operating two Michigan refineries, is installing a two-coil cracking unit in its Detroit plant. At the present time, this plant is processing 3000 bbl. per day of Illinois crude oil. The company's plant at Elsie, Michigan, is processing 2500 bbl. of Michigan crude oil. The new unit, to have a rated capacity of 1800 bbl. per day of topped Illinois crude oil, will be arranged for later conversion to a combination topping, cracking, and reforming unit having a combined capacity of 4000 bbl. per day. The contract for the construction work was awarded to Mid-Continent Engineering Company.

●

As a result of arrangements to double the amount of gas sold under contract to Cities Service Gas Company from the Cunningham pool in Kingman and Pratt Counties, western Kansas, Skelly Oil Company will immediately begin work on the necessary additional equipment required to treat and dehydrate the additional volume of gas. Previously, the contract between the two companies required the transfer of a minimum of 8,000,000 cu. ft. and a maximum of 20,000,000 cu. ft. per day. The new contract calls for Skelly to treat and dehydrate double this amount, i.e., a 16,000,000 cu. ft. minimum and a 40,000,000 cu. ft. maximum per day.

●

Richfield Oil Corporation has completed plans for the construction of an alkylation unit at its Watson, California, refinery. The new work will involve an expenditure of approximately $700,000.

Gasoline Production Corporation plans to build a recycling plant in the Grapeland field, southeast Texas, according to a recent announcement. Distillate Engineering and Process Company has licensed the equipment to be installed in the plant. The construction of the plant has been contracted to H. B. Zachery Construction Company, San Antonio, Texas, and will be designed by Eureka Process Company. This is the seventh plant to be licensed under D.E.P. Company patents.

●

Essex Refining Company, a newly organized Michigan company, has started construction of a 1500-bbl. topping plant at Essexville, Michigan. The refinery is in answer to a need for an outlet for crude oil produced in the Wisner oil field, Tuscola County, Michigan. Because of a comparatively high sulphur content, it has been found difficult to interest refiners in purchasing the oil. According to the present schedule, the plant should be in operation by June 15.

●

Tide Water Associated Oil Company recently announced that it has taken a license from the Houdry Process Corporation for 15,000 bbl. of catalytic refining capacity per day. In connection with this license, Tide Water Associated Oil Company has awarded a contract to E. B. Badger and Sons Company for the design and construction of the unit, to be located at the company's refinery at Bayonne, N. J., replacing older-type facilities.

The company has also recently installed at its refinery in Avon, California, additional cracking facilities and a polymerization plant for the production of a high anti-knock gasoline and for improving its straight-run gasoline. At present the company has in course of construction an alkylation plant at its Avon refinery for the purpose of making higher-octane gasoline of aviation specifications at lower cost.

The new unit at the company's Bayonne refinery should be completed and in operation during the latter part of this year.

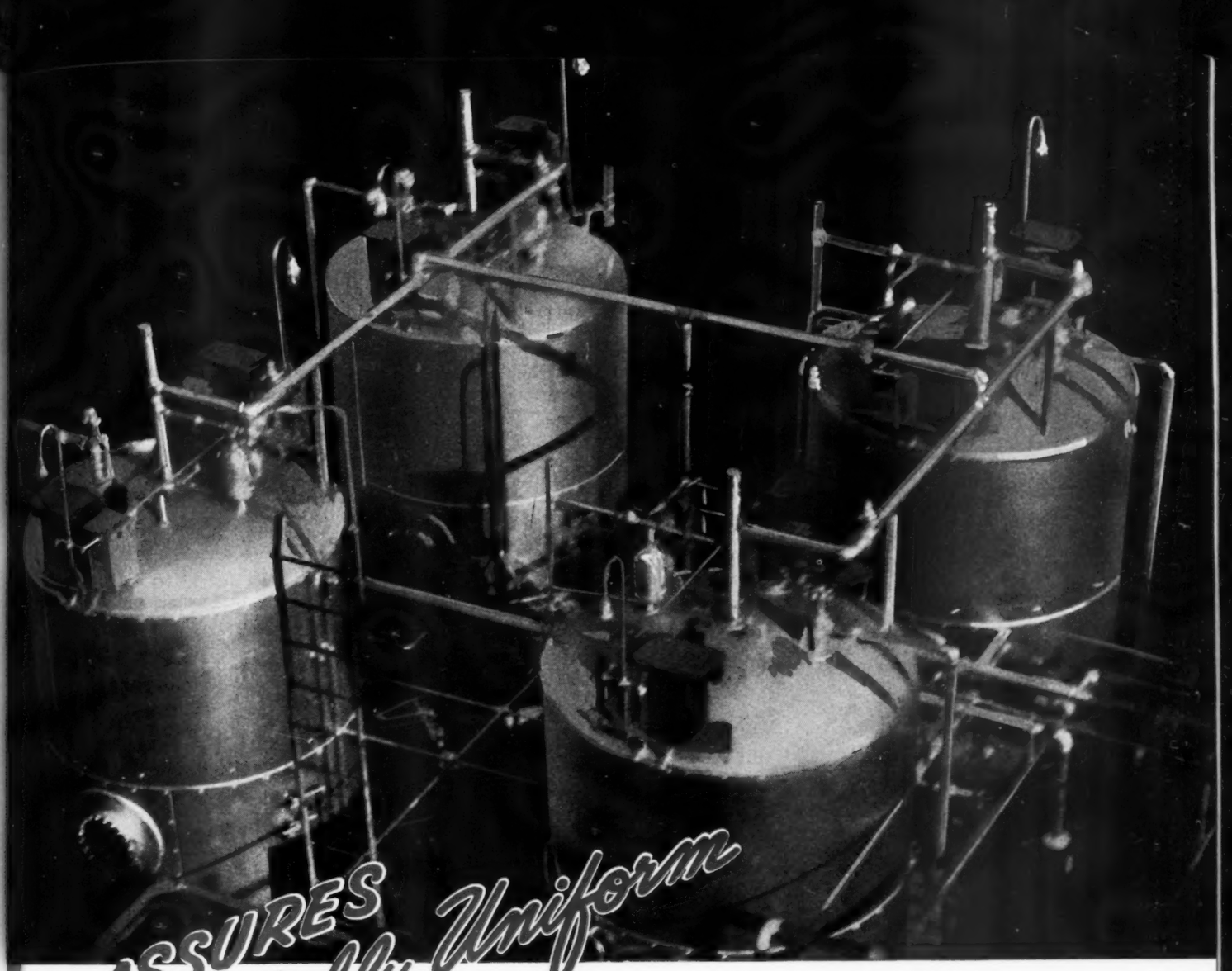
●

Attempts by labor unions in Louisiana to dictate terms has caused Continental Oil Company to withhold the signing of any contracts for the construction of the proposed refinery at Lake Charles, Louisiana, until the situation becomes clarified. The company recently announced its plans to build a $4,000,000 refinery at the Louisiana city but it may abandon these plans unless a satisfactory arrangement concerning labor can be made.

Crude Runs to Stills, Gasoline, Gas and Fuel Oil Stocks
Week Ended May 4, 1940
A. P. I. Figures
(Figures in thousands of bbl. of 42 gal. each)

DISTRICT	Percent Potential Capacity Reporting	Daily Average Crude Runs to Stills	Percent Operated of Total Capacity Reporting	Total Motor Fuel Stocks	Total Gas and Fuel Oil Stocks
East Coast	100.0	535	83.2	23,615	13,923
Appalachian	91.0	118	83.1	4,140	1,012
Ind., Ill., Ky.	88.5	548	97.7	18,179	5,716
Okla., Kans., Mo.	76.9	291	90.1	8,161	2,875
Inland Texas	59.6	108	64.7	1,924	1,732
Texas Gulf	85.3	858	93.9	15,308	8,476
La. Gulf	97.6	127	79.4	2,972	1,891
No. La. and Ark.	51.5	36	69.2	620	624
Rocky Mt.	55.5	37	56.1	1,699	755
California	87.3	485	66.4	18,375	88,312
Reported	84.9	3,143	83.6	94,993	125,316
Estimated Unreported	.....	362	.....	7,070	3,385
*EST'D TOTAL U. S. MAY 4, 1940	.....	3,505	.....	102,063	128,601
*EST'D TOTAL U. S. APR. 27, 1940	.....	3,555	.....	102,452	127,549
U. S. B. of M. *MAY 4, 1939	.....	**3,368	.....	87,101	136,167

*Estimated U. S. Bureau of Mines' basis.
**April-May, 1939, daily average.



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The refinery now is obtaining long continued runs with shutdowns being required only for regular inspections. The day to day operation of the refinery unit is remarkably uniform. There are no peak loads and speeding up after a shut-down to make up lost time. After thirty to sixty days operation the heat exchangers are still clean and it is unnecessary therefore, to increase the furnace load to compensate for loss of heat. It has, however, been found possible to fire the cracking furnace harder and thereby increase the yield. No trouble with coking of the visc breaker furnace has been experienced since the Petreco Desalter was installed.

Such uniformity is only one of many outstanding advantages of Petreco Electromatic De-Salting that are essential to safe, efficient and economical refinery operation. Refinery executives will be vitally interested in complete details, which will be supplied on request.

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DE-SALTING and DEHYDRATION PROCESSES

Activities in the Oil Fields

WELLINGTON Oil Company's No. 1 L. Ranch Company, three miles northwest of Lolita, Jackson County, Texas, ran an 8-min. test from a depth of 5824-44 ft., during which 50 ft. of oil-cut mud was recovered, giving good indication of another new oil field on the upper Texas Gulf Coast. Bottom-hole pressure was 1900 lb.; the oil recovered tested 40° A.P.I. gravity. The operators then cored ahead and in a 9-min. test from a depth of 5861-76 ft. recovered distillate. Operators resumed coring, confident that a commercial well will be obtained.

●

A new field five miles southeast of the Yates field, Crockett oil in Soma No. 1 W. T. Noelke a well situated in section County, Texas, is indicated as a result of the discovery of 30-GG-HE&WT. A 4-hr. test by the Railroad Commission gauged 130 bbl. of 32.2° A.P.I. gravity oil during the test, or, on a 24-hr. basis, 780 bbl. Production is from the Yates zone at a depth reported as between 1039 and 1075 ft. The rate of gas production was 19,000,000 cu. ft. per day after heavier gas flows encountered as the well was being drilled had been controlled.

●

Pawnee Royalty Company's No. 1 Bucholz, C NWSW 17-1n-16e, Richardson County, Nebraska, produced 20 bbl. of 32° A.P.I. gravity oil per hr. to mark a definite discovery of oil in the Forest City Basin. The well drilled into the Hurton limestone at a depth of 2217 ft. and the hole was bottomed at 2250 ft. After acidizing the formation with 500 gal. of acid and swabbing 30 bbl. per hr. for seven hr., the well began flowing. The well was making no water with the oil. Production on the pump is expected to be 450 bbl. per day.

A second producing area for Stonewall County, Texas, is assured by the discovery of oil from a formation of Mississippian age. Thirteen ft. of saturated limestone had been drilled at the time the well started flowing. In the initial 24-hr. test, the well produced 280 bbl. of 39° A.P.I. gravity oil from a depth of 6015-28 ft. The well is situated in the center of a 5137-acre block eight miles south of Aspermont, Texas, and ten miles north of Hamlin, Texas.

●

A new discovery two miles west of the North Ward field, Ward County, Texas, obtained oil production of 40 bbl. per hr. The well, No. 1 Wickett-University, drilled by Atlantic Refining Company, is in section 12-16-U. Casing is set at a depth of 2838 ft.

●

A new pool between the West Prusa and Feltes pools in Barton County, Kansas, is assured by the completion as a producer of No. 1 Hoffman, drilled by M. B. Armer and Vernon Oil and Gas Company. After acidizing, the well gauged a top allowable potential of 3000 bbl. per day. The Arbuckle limestone was encountered at a depth of 3318 ft. and the well was bottomed at 3321 ft. The well is situated at C WL NW SW 18-16-11w.

●

General Petroleum Corporation's No. 1-21-G, NW NW NW 21-35n-77w, Natrona County, Wyoming, has tapped a new producing horizon in the Cole Creek district. After drilling to the Lakota formation at a depth of 8050 ft. and obtaining an unfavorable test, the well was plugged-back and casing perforated opposite the Shannon sand at 4530-70 ft. The well was first swabbed at the rate of 400 bbl. per day. Through tubing, the well is flowing 195 bbl. per day.

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Montana	.90-1.10
Wyoming	.35-1.30
Colorado	.90- .98
New Mexico	.53- .95
Texas	
North Central	.71-1.03
Panhandle	.67- .96
West Texas	.53- .95
Gulf Coast	.86-1.28
Darst Creek	.96
East Texas	1.10
Talco	.65
Kansas	.60-1.10
Oklahoma	.60-1.10
Arkansas	.73-1.05
Louisiana	
Rodessa	$1.05
Gulf Coast	.79-1.28
North Louisiana	.73-1.05
Illinois	.95-1.05
Kentucky	.90-1.10
Indiana	.95
Ohio	
Lima	.90
Michigan	.74-.97½
Pennsylvania	
Bradford	2.75
Southwest	2.40
Eureka	2.34
Buckeye	2.30
Corning	1.12
Canada	2.10-2.17

DAILY AVERAGE CRUDE OIL PRODUCTION

Data Supplied by A. P. I.

(Figures in bbl. of 42 gal. each)

	[1]B. of M. Calculated Requirements (May)	Week Ended May 4, 1940	Week Ended March 30, 1940	Week Ended May 6, 1939
Oklahoma	408,100	[2]409,350	402,050	459,550
Kansas	158,100	[2]147,650	180,400	167,900
Nebraska		[2]		
Panhandle Texas		77,550	82,200	87,300
North Texas		102,600	104,600	81,950
West Central Texas		33,050	33,900	30,800
West Texas		233,300	276,650	230,000
East Central Texas		80,900	91,150	105,850
East Texas		396,650	396,900	447,000
Southwest Texas		214,100	270,350	253,100
Coastal Texas		229,650	255,050	234,000
TOTAL TEXAS	1,344,200	1,367,800	1,510,800	1,470,000
North Louisiana		69,500	68,800	75,700
Coastal Louisiana		224,500	212,900	192,700
TOTAL LA.	264,500	294,000	281,700	268,400
Arkansas	64,500	69,100	69,000	55,450
Mississippi	5,800	[2] 7,800	7,850	
Illinois	392,900	421,550	426,950	390,200
Indiana	8,100	[2] 9,600	8,500	
Eastern (Not incl. Ill. and Ind.)	101,300	100,400	96,300	99,450
Michigan	63,200	62,250	64,300	62,950
Wyoming	72,900	66,400	68,750	58,900
Montana	17,400	17,500	17,000	14,450
Colorado	3,500	3,750	3,900	3,600
New Mexico	103,900	106,800	112,550	110,750
TOTAL EAST OF CALIF.	3,008,400	3,083,950	3,250,050	2,971,600
California	592,600	595,100	591,200	609,300
TOTAL U. S.	3,601,000	3,679,050	3,841,250	3,580,900

[1]These are U. S. Bureau of Mines' calculations of the requirements of domestic crude oil based upon certain premises outlined in its detailed forecast for the month of May. As requirements may be supplied either from stocks, or from new production, contemplated withdrawals from crude oil inventories must be deducted from the Bureau's estimated requirements to determine the amount of new crude to be produced.

[2]Oklahoma, Kansas, Nebraska, Mississippi, and Indiana figures are for week ended 7 a. m., May 1.

Great Pioneers
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Old Fort Laramie—first permanent settlement in Wyoming—the rendezvous and refuge of trappers, traders, home seekers and adventurers during pioneer times. In the heart of the Indian country, this outpost was the site of many uprisings, likewise many peace councils. Wyoming was admitted to the Union in July, 1890. Among a list of 22 sister states she ranks tenth in petroleum production for 1939.
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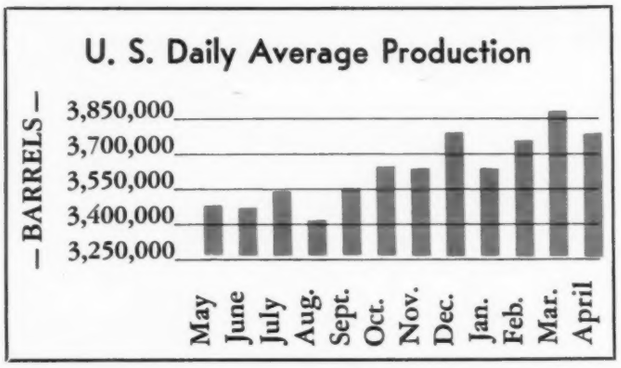
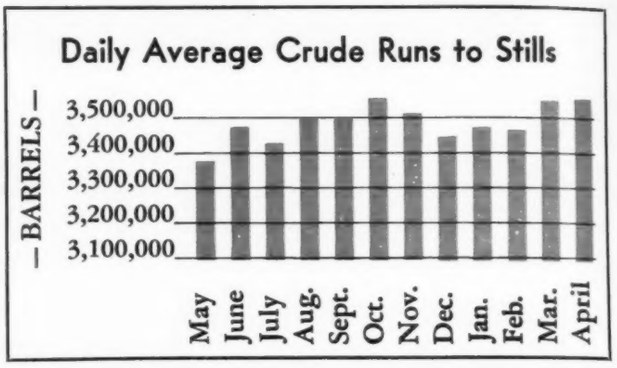
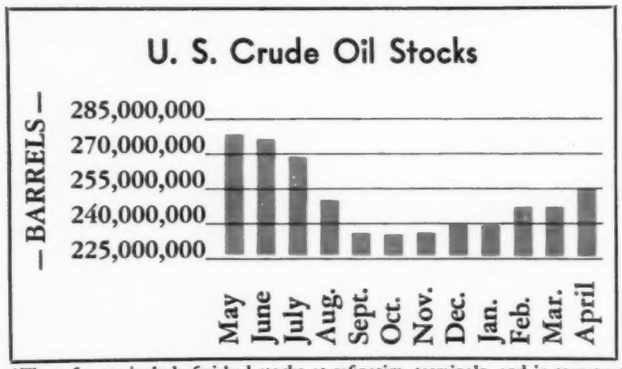
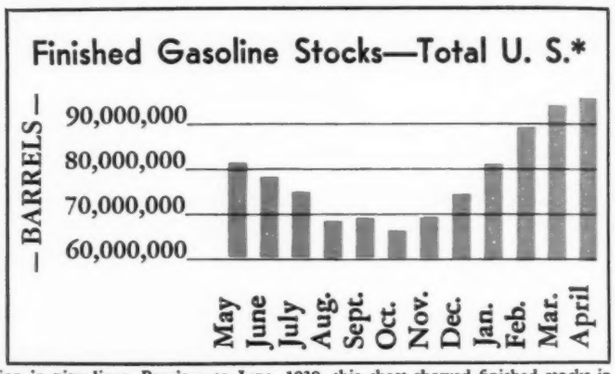
Petroleum Statistics and Field Activities









*These figures include finished stocks at refineries, terminals, and in transportation in pipe lines. Previous to June, 1939, this chart showed finished stocks in refineries only. Above statistics by the American Petroleum Institute.

Summarized Operations in Active Fields for April, 1940

Fields	Completions	Producers	Rigs	Drilling	Depth of Production	No. Casing Strings	Gravity of Oil	Type of Tool Used
Texas								
East Texas	18	18	6	11	3500-3700	2	40	Rotary
Duval County	39	20	5	13	1554-2900	2	22	Rotary
Ector County	49	37	24	66	3675-4377	2 and 3	32-36	Rot.-Cab.
Panhandle	45	38	10	47	1700-3900	2	40	Rotary
Refugio County	7	5	3	4	4900-5900	2	38	Rotary
Nueces County	10	8	1	6	3922-5878	2 or 3	21-54	Rotary
K. M. A. Field	24	23	30	46	3730-3935	2	42-43	Rot.-Cab.
Oklahoma								
Fitts Pool	15	11	2	4	1800-4488	2 or 3	38	Rotary
Kansas								
Russell County	18	14	8	22	2926-3435	2 and 5	32-37	Rot.-Cab.
Rice County	15	11	5	21	3222-4085	2 and 5	42-48	Rot.-Cab.
Barton County	16	14	4	19	3290-3518	2	39-42	Rot.-Cab.
Illinois								
Central Illinois	252	250	187	98	1425-4100	2	36-38	Rot.-Cab.
New Mexico								
Lea County	27	26	13	45	3150-4030	3	30-34	Rot.-Cab.
California								
Kettleman Hills	15	14	12	10	8300-8730	3 or 4	40	Rotary
Wilmington	....	....	....	....	3500-4000	2 and 3	18-20	Rotary

Field Activities by States for April, 1940

State	Completions		Producers		Locations		Rigs		Drilling Wells		Production, 1939 (In Barrels)
	April	March	April	March	April	March	April	March	April	March	
Arkansas	16	15	14	10	10	16	5	4	32	36	21,266,994
California	113	102	101	90	87	96	72	76	184	188	224,336,682
Colorado	....	....	....	....	....	....	0	1	19	22	1,402,599
Illinois	287	300	255	274	155	277	254	325	136	130	92,915,620
Indiana	26	32	18	24	....	....	3	5	59	66	1,426,000
Kansas	162	132	119	105	196	157	42	40	179	183	59,952,340
Kentucky	6	17	5	9	....	....	7	9	88	90	5,611,500
Louisiana	124	118	106	89	98	149	37	35	195	192	94,110,736
Michigan	74	95	63	49	82	92	59	54	175	172	23,185,203
Mississippi	16	13	9	8	....	....	5	3	19	24	102,918
Montana	13	6	12	3	....	....	6	4	31	36	5,901,058
New Mexico	64	51	60	46	44	55	28	23	146	137	37,453,117
New York	86*	97*	80*	96*	....	....	21	24	72	77	5,105,000
Ohio	44*	58*	19*	50*	....	....	47	53	156	160	3,157,500
Oklahoma	183	160	143	98	156	174	59	53	302	295	156,421,939
Pennsylvania	184*	191*	167*	181*	....	....	....	....	....	....	17,342,500
Tennessee	0	2	0	1	....	....	....	....	....	....	....
Texas	787	875	548	655	1081	805	452	433	1415	1371	485,847,999
West Virginia	29	32	21	26	21	....	24	20	109	114	3,556,500
Wyoming	10	11	10	10	....	....	5	7	48	56	21,408,478
Total	2224	2307	1750	1824	1930	1821	1126	1169	3365	3349	1,260,504,683

*Includes water-intake and pressure wells.

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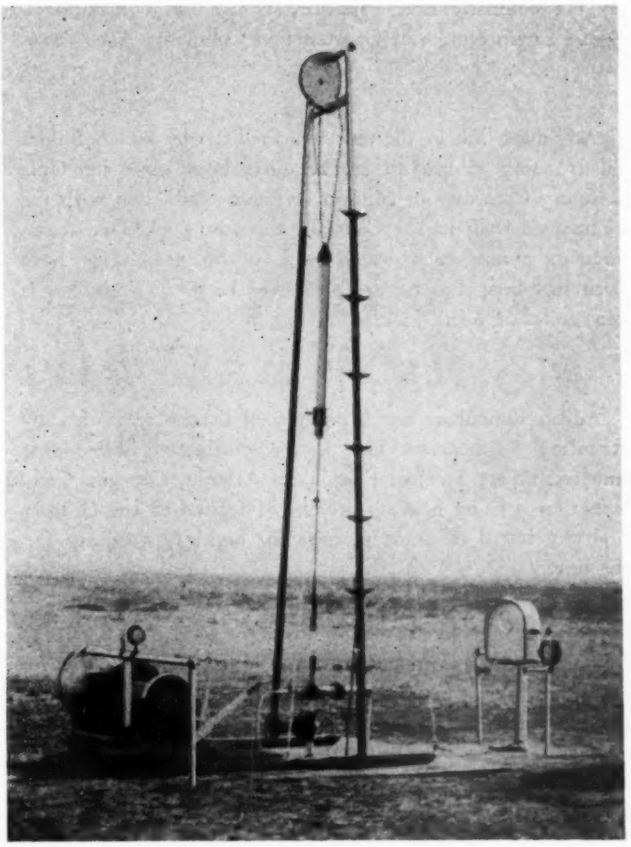

The EXCLUSIVE AND PATENTED method of setting a series of flow valves in the tubing string at time of installing a Nixon Surface Control Gas-Lift System means you can produce from highest flow level to "off-bottom" without disturbing the original installation. This saves the cost of purchasing and installing additional equipment; the time and work involved in relocating the flow valve to correspond with the level of flow, thus further enhancing the economy of the Nixon Gas-Lift System.

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When you install Gas-Lift, look beyond the operation of the original installation. Get the Nixon Surface Control Gas-Lift System and follow the flow levels all the way down without disturbing the sub-surface equipment. Talk to a Nixon Gas-Lift Engineer for complete details. Write your nearest Wilson Supply Co., store or sales office.

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Major Pipe Line Activities

THE CONTRACT to construct ten miles of gathering and return lines has been awarded by Hunt Oil Company in connection with the new recycling plant being built by the company near Palestine, Texas. The contractor is Wood Engineering and Construction Company, Arp, Texas.

•

An added link in the pipe line facilities by which Illinois oil is being moved to markets has been built by Gulf Refining Company to connect its main trunk line with the company's wells in the Centralia townsite pool. Two reciprocating pumps, each driven by a 100-hp. gas engine, have been installed at Centralia to move the oil. The lateral is nine miles of 6-in.

•

Added difficulties are being placed in the way of constructing Southeastern Pipe Line Company's gasoline pipe line from Port St. Joe, Florida, to Atlanta, Georgia. Construction is being held up because of refusal of the Georgia highway board to grant permits for highway crossings for the line.

The situation was somewhat clarified by the recent granting of permits by commissioners of Clayton County, Georgia, for the company to cross under the highways of that county. Previously, permission had been granted by Henry, Baker, Crawford, and Decatur counties, all in Georgia.

•

More than half the 134-mile oil pipe line being built by Stanolind Oil and Gas Company between Bemis and Washington, Kansas, has been completed. The Republican River crossing, installed under a separate contract by C. S. Foreman Company, has been completed.

•

Northern Natural Gas Company, Omaha, Nebraska, is further increasing the capacity of its pipe line system by the installation at the present time of four loops in the states of Kansas and Nebraska. Involved in the new work will be the laying of 60 miles of 24-in., and 50 miles of 12-in., 10-in., and 4-in.

•

In a $3,000,000 expansion program, Southern Natural Gas Company is planning to increase the size of existing compressor stations and to construct approximately 80 miles of 22-in. pipe line looping portions of the existing transmission line from Monroe, Louisiana, to Atlanta, Georgia. The new lines are estimated to increase the ability of the line to meet peak loads by about 15 percent. It is planned to add 13,000 hp. to existing stations.

A 1200-mile pipe line to transport gasoline and other refined products may possibly emerge from present plans of Standard Oil Company (New Jersey) and Shell Oil Company, Inc., to construct such a line as a joint enterprise. The line, if built, would originate in Louisiana and traverse the southeastern states over a route terminating in Virginia.

•

Fifteen miles of 4-in. welded pipe line has been constructed for Fox-Hart-George Pipe Line Company to supply gas to Baird Refining Company's refinery near Baird, Texas, from the Pueblo field in Callahan County. It is planned to extend the line later to other markets, including the sale of gas for repressuring operations.

•

Oklahoma Natural Gas Company has recently replaced two pipe line crossings on the Arkansas River below Tulsa, Oklahoma. The lines replaced had been in service for 30 years. Replacement was warranted because of the failure of the lines to withstand the increased pressures required during the excessive loads on the line during the cold weather of last January.

•

The latest move in the plans to build a pipe line from the Hugoton field, western Kansas, to supply natural gas to the iron mine districts of Minnesota is Kansas Pipe Line and Gas Company's request to the Federal Power Commission to consider a revision of the territory it would serve when the line is completed. The route of the line would pass through the states of Kansas, Nebraska, South Dakota, North Dakota, and Minnesota.

The company's plan now is to serve 102 cities and towns initially and to connect 52 others later. Many of the branch lines would be financed by the distributors purchasing gas. The revised plan reduces the capital required for construction purposes from $21,000,000 to $14,550,000.

•

An aerial survey has recently been completed of the proposed pipe line to deliver natural gas from the Lloydminster field to Saskatoon, in Canada. According to the present schedule, construction of the distribution system in the city of Saskatoon will begin during the latter part of May.

•

Twelve miles of 6-in. pipe line is being constructed by Argus Gas Company to supply natural gas to Garden City, Kansas, from the O. J. Brown gas well, southwest of the city.

•

Michigan Gas Transmission Company is constructing 54 miles of 24-in. pipe line between Montezuma and Crawfordsville, Indiana. T. R. Jones, Dallas, Texas, is the contractor on the job. Work is expected to be completed by September 15.

THE Petroleum Engineer

MAY, 1940

A PETROLEUM ENGINEER EXCLUSIVE FEATURE

Chains and Golf Balls Play Part in "Killing" Wild Gas Well

By K. C. SCLATER
Editor

SHEER ingenuity was displayed in the method employed to "kill" a wild high-pressure gas well at Sinton, San Patricio County, Texas. The well, belonging to the Texas Gulf Producing Company, had blown out and was in a fair way toward causing what might have been serious damage just before it was brought under control. The packer devised for killing the well was as original as it was successful. It involved the use of a chain packer designed on the spur of the moment during the emergency. To obtain a final and absolute shut-off between the tubing and casing, golf balls were lubricated into the well through the tubing. These, in conjunction with the chain packer, did the job immediately and very effectively.

The well had been completed as a gas well at a depth of approximately 6700 ft. and was cased with 5¾-in. casing. After the 5¾-in. casing had been set and cemented through the sand, tension of a few inches was taken, and then the casing welded to a 10¾-in. bradenhead and cut off flush with the 10¾-in. flange on the bradenhead. The 5¾-in. casing was then gun-perforated opposite the gas sand.

The Christmas tree was then connected and consisted of a 4-in. master gate valve below which the tubing was swung on a hanger, the lugs of which were operated from the outside. The outside diameter of this hanger was 3¾-in. and the opening through the Christmas tree 3 13/16 in.

About 6600 ft. of 2-in. external upset tubing was then run in the well,

Crater formed by the gas blow-out

after which the well was washed-in. Within a few hours a hissing noise in the bradenhead was heard. Evidently there was a leakage of gas somewhere in the well. Not very long after that the well blew out at the surface some distance from the well. A small crater formed in the middle of a county road some 150 yards away. It blew there for only a few minutes and then the gas blew out in a water well that had been drilled to supply water for the boilers while drilling. Oddly enough, the water well was 280 ft. deep and was in a direct line between the well and the small crater in the county road.

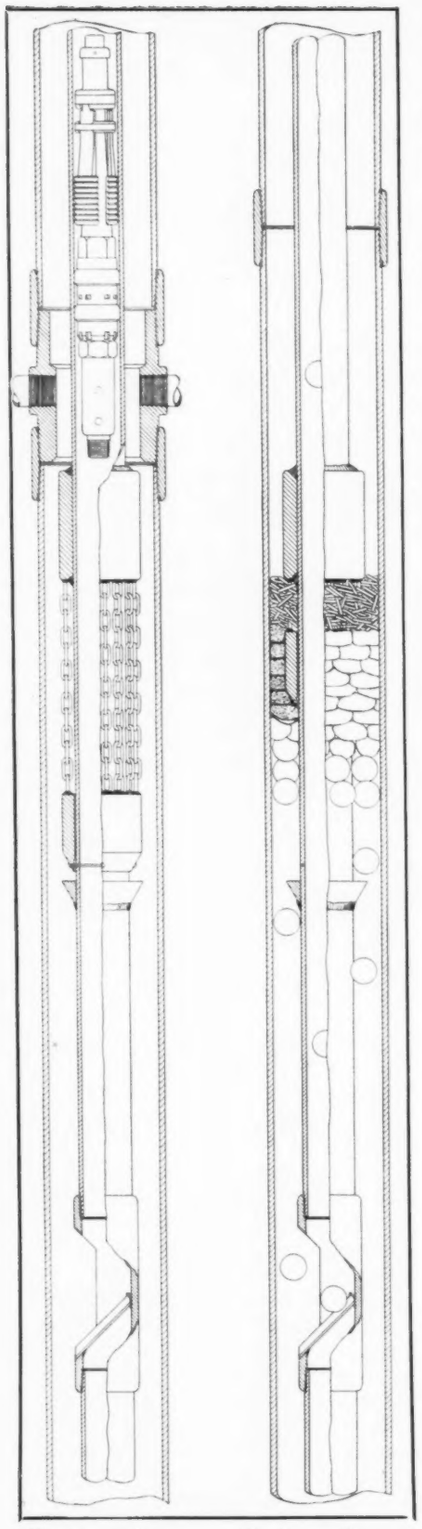
In addition to the 5¾-in. casing in the well a surface string of 10¾-in. casing had been set and cemented at 1000 ft. The pressure at the casing-head when the well was completed was about 2000 lb. per sq. in. After the well blew out the pressure dropped to about 500 lb. per sq. in. After the well had been flowing wild for a few hours, it appeared reasonably certain that the 5¾-in. casing had parted somewhere near the surface and the gas was escaping around the shoe of the 10¾-in. surface casing. It was the belief of company officials that the 5¾-in. casing had parted at the weld in the bradenhead.

An attempt was first made to kill the well by pumping mud down through the tubing. This was unsuccessful. After pumping for some time the mud went out of the tubing so rapidly—probably induced by the upward flow of gas in the 5¾-in. casing—that it formed a vacuum at the tubinghead.

An attempt was then made to kill the well by pumping cement down through the tubing. This was tried but without success. A thousand sacks of cement was pumped as fast as it was possible to pump it through the tubing, but within a few minutes cement appeared in the crater.

It was decided at this point to try to shut off the flow of gas through the 5¾-in. casing by using a packer. An examination at the well showed that the crater was far enough away that the well could probably be worked on with safety. Another favorable factor in this connection was that the well was not making any sand. The crater was creeping gradually nearer the well; however, it was active and the pressure on the casing showed very little change, so there seemed little possibility of the gas breaking out in another place in the vicinity of the well.

When it seemed reasonably sure that



Chain packer before wires holding floating collar were cut

Chains collapsed and golf balls forming seal in casing

the well could be worked-on with safety, equipment for pulling the tubing under pressure was rigged-up. This consisted of regular snubbing and control equipment. As the well was making salt water in quantity, there was no great incentive on the part of the owners to salvage the well, so an attempt was to be made to kill the well in any way possible.

There was 6600 ft. of 2-in. external upset tubing in the well. After 3000 ft. of tubing had been pulled, the flow of gas was found to be so great that the remaining 3600 ft. of tubing in the hole began to float. On the basis of a pressure of one lb. per sq. in. per lineal ft. of tubing the well pressure was estimated at 3600 lb. per sq. in. Rather than run the risk of snubbing out the rest of the tubing and not being able to get back into the 5¾-in. casing with a packer, it was decided to try to kill the well by some means with the 3600 ft. of tubing in the hole.

It seemed certain that if the 5¾-in. casing could be packed off from the tubing near the surface, there would be very little trouble in killing the well through the tubing by pumping mud or cement.

With this purpose in view a spring packer was run on the tubing and an attempt made to obtain a shut-off between the tubing and the casing; but this was unsuccessful. The packer seemed to cling to one side of the casing and the springs, by failing to overlap, left a larger opening by the packer than through the tubing. The spring packer was then taken out and redesigned, but all attempts to run it in the 5¾-in. casing failed.

It was then that the idea of a chain packer was conceived. The construction of this packer is shown in the accompanying sketch. As will be observed, it consists of a number of chains suspended from a collar welded to the outside of the tubing. The lower ends of the chains are welded to another collar that slides or floats freely on the tubing. Just below the floating collar a small beveled ring is welded to the outside wall of the tubing as a safety measure. In running the chain packer into the hole on the tubing the lower, or floating, collar on the end of the chains was held in position on the tubing by small cross wires passing through the lower end of the floating collar and the wall of the tubing (see illustration). Just below the chain packer is a special tubing coupling with a sidewall opening and a deflector for the sealing material pumped down the tubing.

The chain packer was lowered about 20 ft. into the 5-in. casing. A set of heavy clamps were then put on the tubing and these were anchored to heavy clamps in the collar with 1¼-in. steel rods. A gauge tool was then lowered into the tubing and the wires holding the floating collar of the chain packer sheared. A lubricator 5 or 6 ft. long was then connected to the tubinghead and a Halliburton hose connected to the top of the lubricator. The lubricator was then loaded with canvas pills about 6 in. long. These were wrapped tightly with soft wire. After 4 or 5 canvas pills had been pumped down through the tubing a change in the flow of gas was detected, but they did not succeed in shutting off the flow appreciably.

It was then that the golf balls were introduced. About 15 of these at a time were placed in the lubricator. The lubricator was then pumped up to a pressure greater than that in the well. The master gate was then opened and the golf balls pumped down through the tubing. They could be heard to hit on the chains as they flowed back up outside the tubing against the chain packer. Golf balls were fed to the well until the hissing noise in the bradenhead stopped. Altogether, some 150 golf balls were pumped into the well. After about 15 minutes the crater quit erupting. The golf balls had apparently formed an effective seal against the chains as shown in the illustration. Although the space between the small beveled ring in the tubing and the casing seemed too small to allow the golf balls to pass, there was no trouble from this source. The resiliency of the golf balls was such that they were driven past the beveled ring by the gas pressure without the least delay. The pressure on the high-pressure pumps then began to increase and it was quite evident that the golf balls had formed an effective seal.

After the flow of gas through the 5¾-in. casing was shut-off, water was then pumped down the tubing in an attempt to pump it back into the formation to kill the well. A pressure of 3500 lb. on the pumps was necessary before the formation would take any water. The water was then followed with heavy mud. After the water and mud broke through the formation the pressure gradually decreased to about 600 lb. Enough cement was then pumped in to fill the hole from top to bottom, and so was completed effectively the job of killing the well.

The description of killing this well was as reported by I. A. Miller, manager at Houston for Otis Pressure Control, Inc. He it was who conceived the idea of the chain packer and golf balls. In doing so, he exercised a rare mechanical skill and ingenuity and applied them with the utmost effectiveness in an emergency.

The Compressibility of Gases

V. Vapor-Liquid Phase Equilibria in Hydrocarbon Systems

By GEORGE GRANGER BROWN
Professor of Chemical Engineering, University of Michigan

BASIC ASSUMPTIONS

AT LOW pressures when the vapors may be assumed to follow the ideal gas laws, the combination of Dalton's Law of partial pressure, and Raoult's Law of partial vapor pressure as set forth in equation (30) is widely used to compute the equilibrium composition between liquid and vapor phases:

$$xp = yP \quad . \quad . \quad . \quad . \quad . \quad . \quad (30)$$

where

x = mol fraction in liquid phase
y = mol fraction in vapor phase
p = vapor pressure of pure components
P = total pressure on the system.

Another way of expressing the equilibrium between liquid and vapor phases is by the ratio of the mol fraction of the component in the vapor phase to the mol fraction of the same component in the liquid phase, as indicated in the following equation:

$$K = \frac{y}{x} = \left(\frac{p}{P}\right)^{*} \quad . \quad . \quad . \quad (31)$$

The ratio $\frac{y}{x}$ or K, is in general use under the name of "equilibrium volatility ratio" or "equilibrium constant" as applied to liquid-vapor equilibria. As indicated it may be estimated from the vapor pressures of the pure components under low-pressure conditions when the ideal gas laws may be said to apply. But in high-pressure work, the deviations from ideal gases, the effect of total pressure on the vapor pressure, and the approach to the critical temperature and pressure of the mixture have such pronounced effect on the equilibrium conditions that the results obtained by use of Dalton's and Raoult's Laws are wholly unsatisfactory.

If the compressibility factor, Z, as described in the earlier articles of this series, is used to compute the fugacity of the hydrocarbon as a function of temperature and pressure, the values

*When equation 30 is valid.

GEO. GRANGER BROWN

for the equilibrium contants may be computed for ideal solutions by means of equation (32) (see *Industrial and Engineering Chemistry*, Vol. 24, p. 517, May, 1932).

$$K = \frac{y}{x} = \frac{f_L}{f_V} \quad . \quad . \quad . \quad . \quad (32)$$

in which

f_L = fugacity of pure component in liquid phase at the temperature and total pressure of the equilibrium

f_V = fugacity of pure component in vapor phase at equilibrium temperature and pressure.

Even the use of the fugacities is not entirely satisfactory as it is impossible to compute the fugacity throughout the entire range in which the equilibrium constants are desired (as for a vapor under a pressure greater than its vapor pressure and at a temperature below its critical); consequently the relationship given in equation (32) is not correct for conditions approaching the critical. For these and other reasons it is considered best practice to use values for the equilibrium constants based on experimental data and to avoid the complications involved in using the fugacity relationship.

The binary system ethane-heptane. The manner of treating the equilibrium constants can best be explained by referring to a binary system such as ethane-heptane, which was thoroughly investigated by Kay *(Industrial and Engineering Chemistry*, Vol. 30, p. 459, April, 1938).

In Fig. 10 the curve labeled C_2H_6 is the vapor pressure curve for pure ethane showing the critical point, C, for ethane, at 89°F. and 712 lb. per sq. in. absolute, at the upper end of the vapor pressure curve. Similarly the curve marked C_7H_{16} is the vapor pressure curve for normal heptane showing the critical point, C_7, at 512°F. and 397 lb. per sq. in. absolute, at the upper end of the vapor pressure curve. Intermediate of these two vapor pressure curves are shown the envelopes enclosing the two-phase regions for three different mixtures of ethane and heptane as indicated. The critical point for each of the three different mixtures or systems is indicated by C_1, C_2, C_3.

For a pure substance such as ethane or heptane, two phases can exist in equilibrium at only one pressure for a given temperature. The locus of these points at which vapor and liquid may exist in equilibrium is the vapor pressure curve of a pure compound.

In the case of a two-component system, two phases may exist in equilibrium over a range of pressures for any specified temperature. The region within which two phases may exist in equilibrium is the area enclosed by the envelope for the given mixture as indicated in Fig. 10.

Outside the envelope of a given mixture, that mixture can exist in only one phase. At any point not on the vapor pressure curve of a pure component, that substance can exist only in one phase.

The line A_1C_1, and the corresponding lines A_2C_2, and A_3C_3, are called bubble-point lines because whenever the two-phase region within the envelope is entered by crossing one of these lines, the second phase appears as a bubble of vapor. The line B_1C_1, and

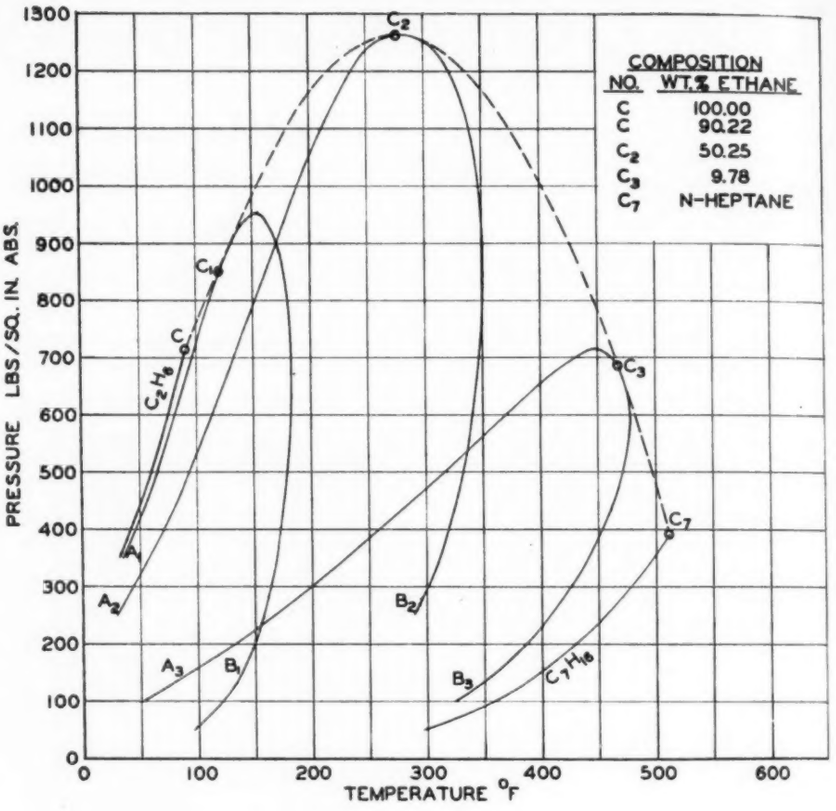


Fig. 10 — Pressure-temperature diagrams for ethane-heptane system *(W. B. Kay, Ind. Eng. Chem. 30, 459, 1938)*

the corresponding lines B_2C_2, and B_3C_3, are known as dew-point lines because whenever the two-phase region within the envelope is entered by crossing these lines, the second phase appears as drops of liquid, or a more dense phase, similar to dew.

In the case of a single substance the vapor pressure curve may be regarded as a dew-point curve superimposed on a bubble-point curve, because the liquid and vapor can exist in equilibrium only at one pressure for any specified temperature.

The phase rule. The number of independent variables that must be fixed to determine completely a given system at equilibrium under a uniform temperature and uniform pressure is given by Gibbs' phase rule, usually expressed as follows:

$$n = c - p + 2 \quad . \quad . \quad . \quad . \quad (33)$$

where

n = the number of degrees of freedom or independent variable that must be fixed to define the system

p = the number of physically separable phases

c = the least number of components required to express the composition of each and every phase.

Applying the phase rule to a pure substance such as ethane occurring in two phases, liquid and vapor, in equilibrium: p is 2, c is 1, and n is 1. It is necessary, therefore, to fix only one independent variable in order to define the system. If the temperature be fixed, the pressure and the composition of each phase are then completely determined; or if the pressure be fixed, the temperature is determined as indicated by the vapor pressure curve.

On the other hand, if we have a mixture of two components such as mixture 2 in Fig. 10 containing 50.25 weight percent ethane, and 49.75 weight percent heptane, present in two phases at equilibrium: c is 2, p is 2, and n is 2. It is necessary, therefore, to fix two independent variables in order to define this two-component system present in two phases. If the composition of the liquid phase be fixed, as for example at 50.25 percent ethane and 49.75 percent heptane, and the temperature is fixed at 200°F., then the pressure is determined by reading on the bubble-point curve for that system, 1050 lb. per sq. in. absolute. Similarly, if the temperature and pressure be fixed, then the system is completely defined and the composition of the liquid phase and the composition of the vapor phase are fixed.

Values of K fixed by temperature and pressure. As the composition of the liquid phase and the composition of the vapor phase in a binary system are completely determined whenever the temperature and pressure are fixed and there are two phases in equilibrium, it follows that the mol fraction of ethane in the vapor phase, y, and the mol fraction of ethane in the liquid phase, x, are also fixed whenever the temperature and pressure are fixed. The value of the ratio, K, or $\frac{y}{x}$ therefore, is determined for ethane in the ethane-heptane system whenever the temperature and pressure of the vapor-liquid equilibrium are known.

Similarly the value of K for heptane in any mixture of ethane and heptane is also fixed whenever the temperature and pressure of the equilibrium are fixed.

This principle may be demonstrated by referring to Fig. 11 on which are plotted the values of K or $\frac{y}{x}$, for ethane and heptane as functions of pressure for different temperatures. The values shown as solid lines are those experimentally determined by Kay for the ethane-heptane system. The "ideal" values for K, based on experimental data on a number of different systems, are also shown as dashed lines for comparison. These ideal K values are the values of K for ideal solutions in which the effect of the critical is not considered. The values computed by Raoult's and Dalton's Laws as given in equations (30) and (31) are also shown for heptane as straight lines for comparative purposes.

At the critical point the composition of the liquid is the same as the composition of the vapor, the bubble-point curve joins the dew-point curve, and the values of K for all components in the mixture become unity. By referring to Fig. 10, the locus of the critical points of the different mixtures is shown as the dashed line through the points C, C_1, C_2, C_3, and C_7. Reading from this line, the critical pressure corresponding to any critical temperature may be readily determined. The critical pressure for any temperature so determined defines the value for the pressure in Fig. 11 at which the values

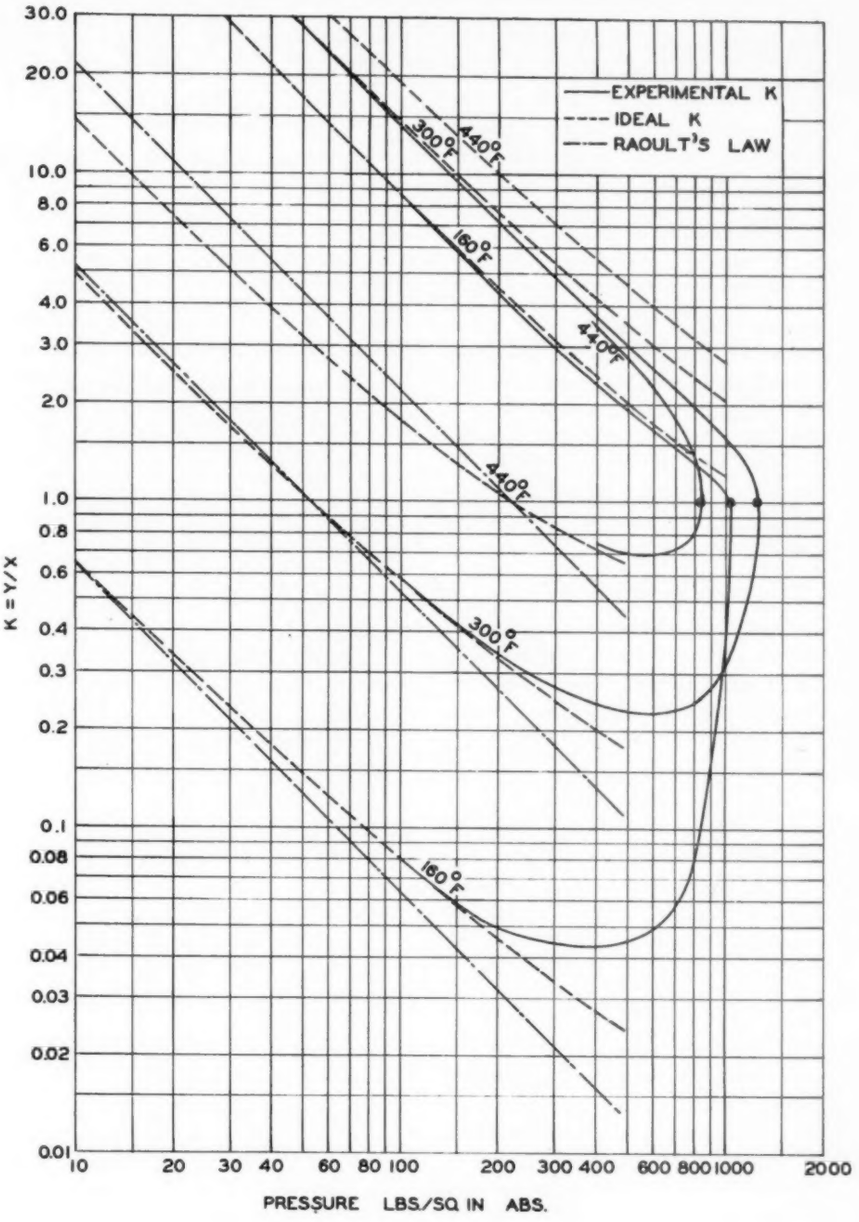


Fig. 11—Equilibrium constants for the ethane-*n*heptane system *(W. B. Kay, Ind. Eng. Chem. 30, 459, 1938)*

of K for that temperature must equal unity.

For example, in the case of the ethane-heptane system, suppose it is desired to determine the equilibrium constants for a temperature of 160°F. By referring to Fig. 10 it is found that the critical pressure corresponding to a temperature of 160°F. is 1020 lb. per sq. in. absolute. The values of K, therefore, for both ethane and heptane must be unity at 1020 lb. per sq. in. for the isotherms of 160°F. as indicated in Fig. 11.

At a pressure equal to the vapor pressure of the pure substance for any given temperature, the value of K is also usually unity, as vapor-liquid equilibrium will exist for that pure compound on the vapor pressure curves when $y = x = 1$.

It has been found that the values for K are generally the same for the different mixtures except insofar as they are influenced by approach to the critical point, and except for the effect of composition on the values of K for methane and to a limited extent for ethane. It is possible, therefore, to present a series of "ideal" K's for the various hydrocarbons found in natural gasoline that may be used with satisfactory results in all such mixtures provided the effect of the critical conditions is recognized and the values of K brought to unity at the critical pressure corresponding to each temperature.

The pressure at which the values of K become unity at any temperature, is the critical pressure corresponding to that temperature as indicated in Fig. 10 and not the critical pressure for that mixture in which the equilibrium between the liquid and vapor phases is to be computed.

For example, in referring to Fig. 10, it will be noted that equilibrium between liquid and vapor phases may exist in any one of the three mixtures plotted at a temperature of 160°F. although this temperature is above the critical temperature of mixture 1 and below the critical temperatures of mixtures 2 and 3. In order to compute these vapor-liquid equilibria in any of these three mixtures, or any other mixture of ethane and heptane, at 160°F., the values for K for ethane and heptane as plotted in Fig. 11 for 160°F. may be used. These values of K for 160°F. as shown in Fig. 11 follow the "ideal" values for ethane to about 800 lb., and for heptane to about 200 lb. The effect of the critical conditions on the values of K becomes of significance at lower pressures for the components whose critical temperatures are farthest from the temperature at which the values of K are plotted.

Complex mixtures. The same general characteristics are observed in the case of complex mixtures, as indicated in Fig. 12, which gives the experimentally determined values for K in a natural gas-crude oil system as reported by Katz and Hackmuth *(Industrial and Engineering Chemistry* 29, p. 1072, Sept., 1937).

The foregoing statements, which are rigorously true for binary mixtures, are not theoretically applicable to complex mixtures unless the complex mixture may be considered as composed of two arbitrary components each of which may itself be complex but of constant composition. Whether or not this condition is fulfilled the procedure outlined above on the basis of binary mixtures offers the most satisfactory basis at present available for estimating the values of K in complex mixtures at high pressure, particularly in the critical region.

Although the effect of the critical conditions on the values for K cannot be overlooked, many calculations are necessary at relatively low pressures

TABLE 6

Component	Feed	Overhead distillate		Bottoms	
	Mole fraction x_F	Moles in distillate per mole of feed	Mole fraction in distillate x_D or y_D	Moles in bottoms per mole of feed	Mole fraction in bottoms x_B
C_2H_6	0.0890	0.0890	0.2180		
C_3H_8	0.2714	0.2705	0.6630	0.0009	0.0015
i-C_4H_{10}	0.0805	0.0446	0.1093	0.0359	0.0606
n-C_4H_{10}	0.1935	0.0040	0.0097	0.1895	0.3202
C_5H_{12}	0.1940	.....	.....	0.1940	0.3277
C_6H_{14} plus	0.1716	.....	.....	0.1716	0.2900
Total	1.0000	0.4081	1.0000	0.5919	1.0000

(below 300 lb.) where the "ideal" values for K may be used unmodified.

Postponing further discussion of the values of K in the neighborhood of the critical, the use of the ideal values as given in Fig. 13 will be demonstrated in making computations for the design of a gasoline fractionating column.

APPLICATIONS

The first application of the use of the K's will be in the computation of a dew point, as applied to the determination of the minimum pressure required for a gasoline fractionating column.

Given: the composition of feed for a fractionating column and the material balance as indicated in Table 6.

In determining the moles of each component in the distillate, and bottoms, the separation desired called for no detectable pentane in the overhead. Hence, all pentane and hexanes plus are placed in the bottoms. Similarly there is no detectable ethane in the bottoms so all ethane is placed in the overhead. As the desired bottom product in this case is a commercial natural gasoline the separation of the butanes is not so sharp and considerable *iso*butane and a trace of propane are included in the bottoms while holding the loss of normal butane in the overhead to about 2 percent of the normal butane in the feed.

If the cooling water temperature may reach 85°F. so that the overhead vapors can be cooled to 101°F., compute the minimum pressure required for operation of the column with a partial condenser for reflux as is the case when the overhead distillate is allowed to pass off as a gas and all the condensate is returned as reflux to the column.

The minimum pressure required for operation of the column, or for the formation of liquid reflux at 101°F. may be determined by using equation (34) to calculate the dew point of the distillate gas at this temperature:

$$K = y/x. \quad . \quad . \quad . \quad (32)$$

$$\text{or } x = y/K$$

$$\text{and } \Sigma x = (\Sigma y/K) = 1$$

or

$$x_{C_2} + x_{C_3} + x_{C_4} = (y/K)_{C_2} + (y/K)_{C_3} + (y/K)_{C_4} = 1 \quad . \quad . \quad . \quad . \quad . \quad (34)$$

The composition of the overhead gas is given in Table 6. Its temperature is 101°F. Equation (34) may be solved by assuming various pressures and substituting the value of K for each component at 101°F. and the assumed pressure together with the value of y for the same component. The minimum pressure required for operation of the column is obtained when the sum of all these terms $\left(\Sigma \frac{y}{K}\right)$ for all the components present in the overhead vapors, equals unity.

●

Editor's Note: The discussion of applications of the phase rules will be continued in an early issue.

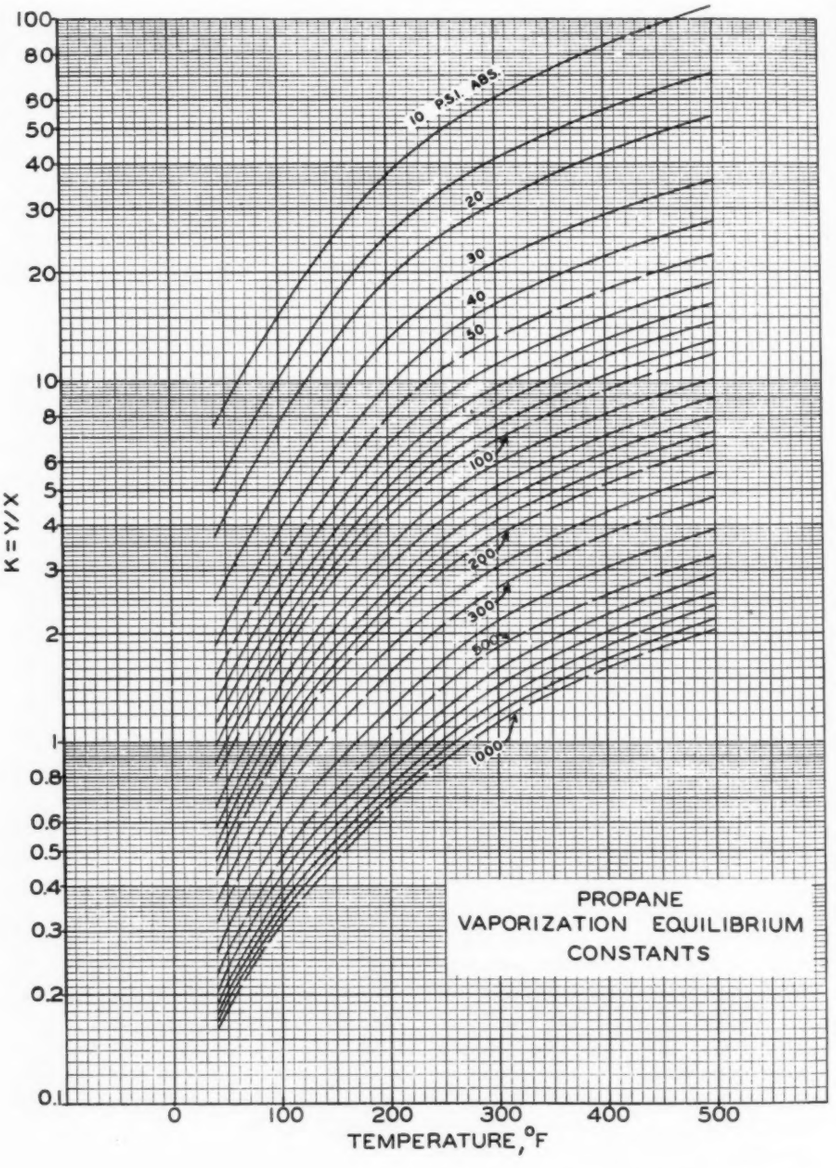


Fig 13-a—Equilibruim constants for propane

P 721.33
P 234.4

The Technology of Refining Processes

Article 5

CATALYSTS AND CATALYSIS IN PETROLEUM REFINING

By

ARCH L. FOSTER

The Lubri-Zol Corporation, Cleveland, Ohio

CATALYSTS are the nearest approach to the Philosopher's Stone, sought by the alchemists of the Middle Ages, that has been made in the history of human progress. The alchemists sought to find a mythical, magical stone or material that could by some occult power transform baser metals into gold, glass into diamonds, and perform similar miracles for the aggrandizement of the man who discovered it. In the groping, never-ending hunt for this stone, the roots of modern chemistry are set. In searching for an impossible thing these superstition-ridden mountebanks unearthed isolated facts about materials that finally won them from a magician's quest to the study of natural laws, and they developed the science on which modern civilization is built.

Definitions for catalysts and catalytic action have been written by virtually every important investigator in the field, yet so far we have no simple, comprehensive statement of just what is included in the meaning of these terms. The catalyst is a helper, a sort of auxiliary locomotive that couples-on to the chemical system, and helps it "over the hump" when otherwise the reaction could not make the grade unaided, or else would move so slowly that the results obtained would have no useful significance. The catalyst causes a reaction to "go" that otherwise either does not occur at all, occurs only extremely slowly, or takes place only at much higher temperatures and pressures than those required to complete it in the presence of the catalyst. For example the dissociation of water, which occurs at a temperature of about 1000°C. without a catalyst, can be effected at 650°C. in an iron tube, in which the iron acts catalytically to lower the temperature of dissociation. Ethyl alcohol decomposes at 750-800°C. in a glass tube (glass having practically no catalytic properties), but in the presence of iron this decomposition begins at 450-480°C., Ipatieff says. (*Catalytic Reactions at High Temperatures and Pressures*, Macmillan Co., 1935). Other similar data dealing with hydrocarbon reactions will be mentioned later in this article.

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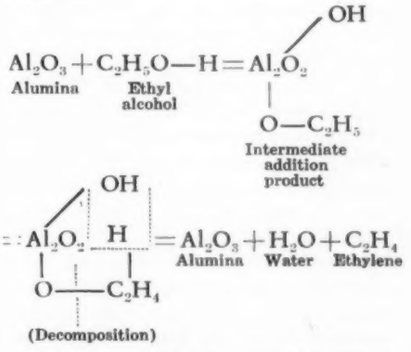
received bachelor's and master's degrees from University of Texas—Since 1922 has variously been associated with the Gulf Refining Company, the U. S. Bureau of Mines, *National Petroleum News*, and at present The Lubri-Zol Corporation—Is a member of the Society of Automotive Engineers, American Chemical Society, American Society For Testing Materials, and Phi Lambda Upsilon, honorary chemical society.

The true catalyst aids or induces the completion of a reaction without itself becoming a part of the final product. Many so-called catalysts are not truly catalytic in action if we hold too closely to this definition, yet their action is so obviously catalytic, that is, they definitely induce reactions that would not otherwise be accomplished, that we must modify the definition to fit known facts. Anhydrous aluminum chloride combines with petroleum hydrocarbons to form a coky, carbonaceous mass from which it is difficult if not impossible to recover the chloride unchanged, by any known means. Yet this material is obviously catalytic in its action, either building up larger molecules from smaller, or "cracking" heavy petroleum molecules to form lighter products of the gasoline boiling range, the nature of the action depending on the conditions of treatment.

Ipatieff (loc. cit., p. 546) divides catalysts into three families. The *first* group he confines to those catalysts that form intermediate compounds with the materials that are to be brought into reaction. These intermediate compounds later decompose and the freed residues or radicals, which were formed by temporary reaction with the catalyst, are brought into reaction with each other. This liberates the catalyst, theoretically unchanged, to carry out the same cycle with new molecules of the reactants. Aluminum chloride is typical of this group, although in reacting with hydrocarbons it appears to combine so tenaciously with part of the hydrocarbon group that a portion of the organic material remains in combination, forming the carbonaceous mass in which the spent catalyst is incorporated.

Senderens, the great French chemist, and his colleague Sabatier, are best known for their development of the hydrogenation of fats, etc., by means of metals and metallic oxide, a reaction widely applied for many years to the solidification of vegetable fats, such as cottonseed oil, to produce much of the cooking fat used by housewives today. Senderens proposed the following mechanism to illustrate the action of this first group of catalysts, typified by the dehydration of alcohol by alumina:

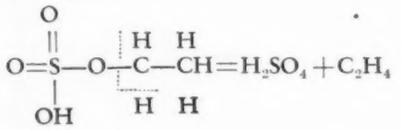


Aluminum hydroxide combines with the alcohol molecule, one hydrogen forming the hydroxyl group with one double-bond oxygen of the alumina and the C_2H_5O— radical being at-

tached to the aluminum atom by the bond so freed from the oxygen; immediately the hydroxyl, —OH, group combines with another hydrogen of the organic radical to form a molecule of water, ethylene is formed, separates from the alumina, which is thus regenerated unchanged to carry out the same cycle again.

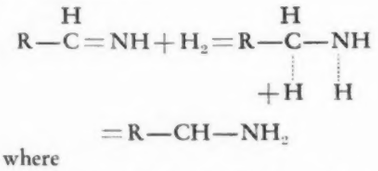
Ipatieff points out that no experimental evidence exists to support such a theory, and states that it may be simpler to explain the dehydration reaction by assuming formation of the alcohol aluminates; even then it is necessary to explain the decomposition of this complex into the olefin, ethylene, and unchanged alumina, for which he states that no evidence is available.

Other catalysts, such as sulphuric acid, however, are known to form these intermediate products. With ethyl alcohol, sulphuric acid yields diethyl ether, $H_5C_2—O—C_2H_5$, when heated under the proper conditions. At higher temperatures and different concentrations the double dehydration occurs and ethylene forms from the same materials. Ethyl acid sulphate forms first, and the $C_2H_5—$ radical from one molecule of the sulphate is later combined with the $C_2H_5—O—$ radical from another, forming the ether molecule, regenerating the acid, and forming a molecule of water. In the formation of ethylene the "break" in the intermediate compound occurs in a different manner, removing a hydroxyl from the $C_2H_5—O—$ radical, probably in this manner:



Whatever the exact mechanism of the reaction the two products, water and ethylene, are formed and the acid is regenerated to catalyze additional reactions.

The *second* group includes "those reactions in which the formation of intermediate compounds is doubtful and the rôle of the catalyst * * * is not understood," as Ipatieff puts it. He terms these reactions eka-catalytic, that is, unknown catalytic mechanisms, the exact route of which we cannot yet explain. This group may be considered to include, for example, those involving the catalysis of reactions by metals or oxides. To illustrate: platinum black or colloidal platinum metal effects the hydrogenation of double bonds between carbon and carbon, and between carbon and nitrogen, almost quantitatively in many cases, yet we have no indication whatever of formation of an intermediate compound between either the double bond and the catalyst or between the hydrogen and the catalyst. Reactions are as follows:



where

R = any organic radical, as C_2H_5.

It is possible that, by so-called secondary or auxiliary bonds a loose, momentary combination of radical or hydrogen and the catalyst may be formed, immediately breaking up, with a union of hydrogen and radical to form the hydrogenated product.

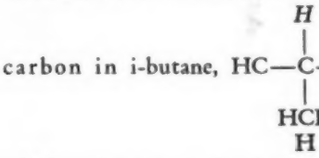
The *third* group of catalysts and catalytic reactions are those involving photo-catalysis, in the presence of light energy or any other energy. This type of catalysis is probably the least understood of all the reactions, although it is used in several processes known today, and nature uses it continuously in the growth of plants and animals.

From the point of view of the petroleum chemist, Ipatieff classifies the reactions of dehydration, polymerization, and alkylation in the first group; that is, these are reactions in which intermediate combinations between catalyst and one or both reactants are formed, the existence of which has been proved in several instances. Following the line of reasoning presented above, it would appear that the reactions of hydrogenation, dehydrogenation, and possibly isomerization and aromatization may belong to the second group, wherein the formation of intermediate complexes are possible but cannot as yet be proved by experimental evidence. As these reactions include most of those of primary interest to the refiner, further discussion of catalysis will be confined largely to these reactions and the catalysts that make them practicable.

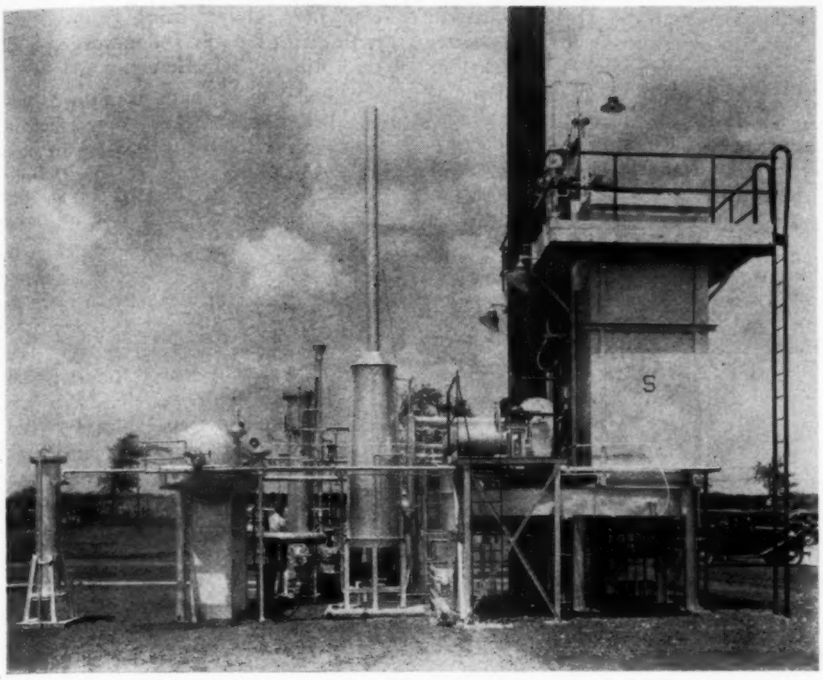
Regarding materials that may be used as catalysts, practically every element in the Periodic Table has been mentioned in the technical literature or in patents, as a catalyst for one reaction or another. In general, catalysts may be divided into: metals and their oxides; acids and substituted acids; salts; organic compounds, and a miscellany of different materials known to have a catalytic effect with certain reactions under certain conditions.

Inorganic acids are among the most common catalysts for organic reactions. Of those, the most frequently used are sulphuric and phosphoric acids. Sulphuric acid catalyzes polymerization and alkylation reactions by the formation of intermediate products. It has been used for years in the dye industry, in the nitration of aromatics such as benzene and toluene to form nitro-compounds, which is accomplished by removal of a molecule of water, taking an —OH group from the acid, a hydrogen from the benzene ring, the two radicals then combining to form nitrobenzene, $C_6H_5—NO_2$, from benzene, C_6H_6, and nitric acid, $HO—NO_2$.

The most interesting application of sulphuric acid is in the alkylation of *iso*paraffins by olefins, a process now being applied in a number of commercial units in this country and abroad, and discussed in an earlier article (Article 3, March, 1940). Acid of 98-100 percent concentration is brought into intimate contact with olefins such as butene and with two to five volumes of *iso*paraffin such as i-butane at temperatures lower than 70°F. Under suitable conditions the acid will induce polymerization of the olefin; it is necessary, therefore, to have a low olefin-paraffin ratio, and the acid must be kept above 90 percent strength or thereabouts, if the reaction is to proceed smoothly and efficiently at the lower temperatures. At these lower temperatures side reactions that reduce the yield of the alkylated *iso*paraffin are practically inhibited.

It is believed that the olefin forms an acid sulphate by addition to the acid radical, displacing an atom of hydrogen and breaking one of the olefin double bonds; under these conditions the olefin will react with the *iso*paraffin, displacing, for example, the most labile or reactive hydrogen of the i-paraffin, that is, the one attached to the tertiary carbon in i-butane,  , which migrates to the free bond of the oxygen just vacated by the olefin radical in the acid and thus rejuvenates the catalyst.

Authorities on this reaction consider now that acid alkyl, or di-alkyl sulphates are formed, with a small portion of the *iso*paraffin being "absorbed" in the acid, and under these conditions the highly exothermic reaction occurs smoothly and rapidly. The olefin is absorbed by the acid at 700 times the rate the *iso*paraffin is taken up, it is claimed (High-Octane Aviation Fuel, etc., Proc. A.P.I., Nov., 1939). The acid finally becomes diluted with dissolved paraffinic hydrocarbons, and with other impurities until it is no longer efficient, and may be regenerated by water dilution to induce separation of the hydrocarbon materials



Large-scale experimental catalytic dehydrogenation unit operated by Universal Oil Products Company at its Riverside, Illinois, research laboratories

and reconcentration of the acid by any of the conventional methods.

Sulphuric acid is also used to polymerize selectively olefins such as butene to form di-*iso*butene (*iso*octene), which is then hydrogenated by metallic catalysts, such as nickel, to *iso*octane, an important component of 100-octane-number aviation fuels. The mechanism is essentially the same as in alkylation except that two olefin radicals apparently unite with the acid, which under heat breaks up by uniting the two radicals with each other and rejuvenating the acid. In all these reactions the activity of the acid increases with temperature, but at the expense of carbonization, increased number and percentage of side reactions, and shortened catalyst life. The lower the acid concentration, the higher must be the temperature to give satisfactory reaction at a practicable rate for commercial operations.

Phosphoric acid, H_3PO_4, has long been known as a dehydrating catalyst, forming esters and acid esters with alcohols, for example, which break up to yield olefins and products from which a molecule of water has been removed, thus regenerating the catalyst. Its all-important commercial use now is as catalyst in the U.O.P. catalytic polymerization process for obtaining motor fuel from cracked refinery gases. Impregnated in solid carriers such as magnesium sulphate or other material, this catalyst may be formed into convenient physical shapes for intimate contact with gases or liquids without some of the drawbacks inherent in the use of a liquid. Presumably, addition products are formed between the acid and the olefins, which break up in the manner outlined previously, and a union of the two olefinic radicals occurs to form a larger olefin molecule. The reaction is strongly exothermic and, probably because of local overheating and the instability of the olefins present, carbon is deposited on the catalyst that necessitates its regeneration by burning off the carbon. The carbon is not a "poison" to the catalyst, apparently, but merely masks its surface and prevents contact between catalyst and reactants.

Fresh phosphoric catalyst converts olefins to olefins of double the number of carbon atoms, quantitatively so long as the carbon deposit does not mask too much of the surface. As Ipatieff's contention is that catalysis is a surface reaction, the greater the amount of surface that can be exposed to contact with the reactants, the greater the efficiency of the catalyst. Every sort of plan is employed, therefore, to subdivide the catalyst as finely as is practicable. It will be shown later that many of the metallic and metal oxide catalysts appear to owe much of their efficiency to the presence of myriads of microscopic pores in their structure, increasing many-fold the surface exposed to contact per unit of catalyst mass.

Much attention has been given recently to the use and effect of auxiliary catalysts or "promoters", which, when added to a given catalyst increase its efficiency, its reaction speed, its life, or all these properties. In some cases the promoter effects reactions that the original catalyst will not catalyze at all, alone. For example, the catalytic effect of aluminum chloride is sometimes very ineffective in the total absence of hydrochloric acid, HCL. In other cases when HCL is not added directly it has been found that the formation of HCL by some decomposition of the catalyst is necessary before action becomes appreciable. Addition of metallic oxides or salts to phosphoric acid increases the speed and completeness of the polymerization action on propene. Propene is polymerized by the acid without the promoter at 150-250°C.; at 120°C., the presence of 10 percent of metallic oxides or salts causes the reaction to occur at a satisfactory rate. A peculiar combination is that of sulphuric and phosphoric acids, in which olefins form the alkyl sulphates, which will not boil without decomposition; with phosphoric acid present these alkyl sulphates are broken up and the lighter hydrocarbon polymers may be distilled readily, being also practically free from sulphur. (Ipatieff, loc. cit., p.634).

Among the most common catalysts in use are the metallic halides. Burk (Proc. Am. Chem. Soc., April, 1939) states that during 1937, 306 references to halides as catalysts were found in the literature. In the list of these materials Burk states that the aluminum halides, especially the bromide, stand at the top of the list in catalytic activity, and those of arsenic and bismuth show the lowest activity. Chlorides and other halides of iron, antimony, titanium, zinc, boron, especially boron fluoride, phosphorus, mercury, columbium, uranium, chromium, zirconium, and many others are cited as catalysts that effect given reactions. Double halides are employed that appear to possess the power of promoting reactions not otherwise accomplishable by a single catalyst.

It is pointed out that many of these halides appear to act as acid-metal acids, that is, $AlCl_3$ plus HCl acts as $HALCl_4$, just as borofluoric acid does. Even in the use of clays that are oxides and silicates of metals, acids are used to "activate" them, which places acids probably as the most important class of catalysts.

Of this family the best known, as mentioned above, is aluminum chloride, usually in the presence of HCl. First famous as the catalyst of the

well-known Friedel & Craft's reaction, which combines two hydrocarbons into a single molecule, and then breaks up larger into smaller saturated molecules, and which also effects several other types of hydrocarbon rearrangements, aluminum chloride is more widely used probably than any other catalyst. It was first used in the petroleum industry to "crack" gas oils to motor fuels—the McAfee process—technically one of the most successful processes yet devised by the industry. It is at present used to increase the "paraffinicity" of heavy oils, thus rendering them more stable to oxidation under elevated temperatures, and giving them higher properties in certain ways, as for example in lubrication. Aluminum chloride is efficient in the polymerization of ethylene, propene, butene, and other olefins, yielding high percentages of naphthenes in the case of ethylene, and di- and tri-polymers and paraffins in the case of propene.

Zirconium chloride is a good catalyzer for polymerization of ethylene and propene. Its reaction rate is less than that with aluminum chloride yet the zirconium salt polymerizes 240 molecules of propene per molecule of catalyst, nearly twice as many as does the aluminum salt. Only one layer of reaction product is formed by zirconium chloride, whereas aluminum chloride gives two layers. Treatment with water separates the zirconium salt almost completely from the single hydrocarbon layer.

Thorium chloride, and the chlorides of iron, beryllium, magnesium, calcium, and lithium show decreasing efficiencies as polymerization catalysts, but space is too limited to discuss their properties in detail. Tantalum chloride shows good catalyst activity in the same field, but lower than aluminum, zirconium, or iron, tantalum polymerizing only 48 molecules of olefin per molecule of chloride, and all products are olefinic in composition.

Metal and Metal Oxide Catalysts

Metals and metal oxides are as widely used for commercial processes as are many other types of catalyst, especially the oxides of heavy metals. Alumina has been referred to as a dehydration catalyst. Alumina, with chromic, iron, or zinc oxides, vanadium sulphate, or reduced nickel as promoters or "activators", has proved to be an excellent catalyst for dehydrogenating hydrocarbons (*National Petroleum News*, Sept. 7, 1938, p. R-432), at temperatures above 585°F. An interesting item in this operation is the necessity for the presence of 0.1 to 0.2 mol percent of water vapor in the reacting gases to complete the reaction satisfactorily. This combination illustrates well the effect of promoters on catalyst efficiency. The nickel or chromic oxide must be supported by the alumina to offer the maximum contact surface, and so adds its own catalytic effect to the lesser effect of the alumina. The role of the water vapor is obscure but it does add some unknown effect that simplifies the otherwise difficult reaction of removing hydrogen atoms from very stable, paraffinic hydrocarbons and results in higher yields.

Grosse and co-workers have perfected the catalytic dehydrogenation of lower-molecular-weight paraffins, using the same kind of catalyst (chromic oxide on alumina in the presence of the water-vapor promoter), dehydrogenating commercially n-butane and i-butane in 85 to 95 percent yields (Proc. A.P.I., Nov., 1939).

In the Houdry process, heavy oils are cracked and unsaturated refinery gases are polymerized by contact at elevated temperatures (750°F. and higher) with a catalyst, for example, 76 percent SiO_2, 17 percent Al_2O_3, and small amounts of ferric, calcium, and magnesium oxides. It is probable that the last three minor constituents are present as impurities remaining from the commercial preparation of the catalyst from bauxite and other earths, and have little part in the activity. Nickel oxide supported on an unnamed base material is used to desulphurize products in the Houdry process, sulphur being almost completely removed, doubtless forming the sulphide of nickel. Similar applications of cobalt and nickel compounds are employed in England, it is reported, to remove sulphur and nitrogen compounds from manufactured gas by the same reaction.

Houdry also treats cracked gasolines by passing them in the vapor phase over catalysts containing manganese and nickel oxides, the clays in which these oxides are found being acid-treated to activate them for use. A hydrosilicate of alumina is used as a reforming catalyst.

Bauxite catalysts—chiefly alumina with appreciable amounts of silica and iron oxide—are used by Phillips Petroleum Company to reform straight-run gasolines, increasing octane numbers from 8 to 25 numbers at temperatures in the range of 750-950°F., with yields of 90 to 98 percent, the yield depending on the nature of the distillate treated and the amount of improvement obtained, improvement and yield being generally in inverse ratio. The same type of catalyst is used to desulphurize distillates, by the same company, sulphur being removed almost quantitatively and increasing lead susceptibility remarkably.

Metallic nickel supported on porcelain has proved to be a very efficient catalyst for the hydrogenation of olefins (*National Petroleum News*, June 15, 1938, p. R-291). This process operates at 15-60-lb. pressure and at less than 400°F., and the reaction is highly exothermic. The catalyst is regenerated by burning with atmospheric oxygen, and then is reduced to the metal by means of hydrogen. The catalyst is poisoned by sulphur, which it removes quantitatively from the reacting vapors. When a catalyst bed has been poisoned until it is no longer efficient as a hydrogenation aid, it is placed in front of the reacting zone to remove sulphur from the incoming gases and thus protect the fresher catalyst from poisoning. When exhausted for this purpose it must be regenerated by removal of the sulphur.

One universal characteristic of oxide catalysts is the fact that there appears to be a definite relationship between their activity as catalysts and their adsorptive capacity. Bauxite, consisting essentially of alumina, is an excellent adsorption filter medium; it is also an active catalyst in cracking and reforming, in desulphurization, and in other important refining reactions. Not all good adsorbents are good catalysts, witness alumina which is active in both fields; on the other hand, silica is an excellent adsorbent but a poor catalyst for most reactions in which alumina excels. A theory is held that catalysis in the presence of metallic oxides is furthered by the adsorption of the reactants, one or both, in intimate contact on the adsorptive surfaces, and that in this manner they are brought in juxtaposition close enough and are "activated" enough to complete a reaction that otherwise will occur only slightly and very slowly, if at all.

Space is not available to treat this tremendously wide and important subject in a more complete manner. Catalysts promise to become one of the most important, if not *the* most important tool in the hands of the refiner, in the preparation of commercial products not practicable to make by using the older, more conventional processes. At present catalysts with one or two exceptions are applied only to light products, motor fuels especially. We have every reason to expect that in the future a similar application of catalysis to the treatment, rebuilding, and synthesis of heavy motor oils will also become commonplace.

Editor's note: Article 6 in this series, "New Methods of Treating Light Distillates" will appear in an early issue.

Electric Equipment on Rotary Drilling Rigs

Two arrangements of equipment are discussed, either of which permits maximum use of available engine power on Diesel-electric rigs—Applications of a-c. and d-c. power in modern drilling

By G. R. PROUT
General Electric Company

THE drilling of oil wells of ever-increasing depths necessarily has caused developments in drilling technique, as well as developments in the drilling equipment for doing the work. Drilling, fishing, milling, pulling stuck pipe, and other work on deep wells have required increased skill and ingenuity on the part of tool pushers, drillers, crews, and others charged with the responsibility of getting the hole down. This work has also required the drilling equipment to be provided with increased power, greater flexibility, and increased maneuverability. At the same time, safety and economy of operation are of prime importance.

Alternating-current electrical equipment, as well as direct-current equipment, has been successfully used on drilling rigs for many years. Power companies and internal-combustion engines have both supplied the energy for electric operation of these rigs.

Deeper drilling in areas where electric power was not available, where water was scarce, and where fuel had to be shipped in, caused interest in and development of Diesel engine-driven rigs. The many outstanding advantages afforded by properly designed d-c. equipment for use with internal-combustion engines caused wide use of Diesel-driven, d-c. electric rigs, especially for deeper drilling in these areas, which included swamp and water locations.

The earlier type of electric drilling rig using internal-combustion engines as prime movers employed two engines each of which drove one d-c. generator and exciter.

When generator voltage control of d-c. motors is used, motors on two or more different types of load cannot take power from the same generator at the same time. On these rigs, therefore, one generator supplied power to the drawworks motor for turning the table and for other work on the drawworks, within the capacity of one engine, and the other generator supplied power to the pump motor. The two generators together were used to supply power to the drawworks motor for hoisting.

As engine sizes on rigs increased, the arrangement using a separate generator on each engine did not permit most effective use of the total power of both engines under drilling conditions. It was found that the engine-generator supplying power to the drawworks motor for turning the table would be loaded only partly; the one supplying power to the motor on the pump would be overloaded and yet the output of the pump would be less than the drilling conditions required.

G. R. PROUT

on September 1, 1939, was appointed manager of sales of industrial control of General Electric Company, with headquarters at Schenectady, New York—Previously he had been acting manager of the southwestern district for the company's industrial department, being stationed at Dallas, Texas—He became affiliated with General Electric in 1923 and after spending a year in the New England District was transferred to the Southwest—Is a graduate of the Massachusetts Institute of Technology, having bachelor's and master's degrees in electrical engineering.

Two arrangements of equipment easily provide a means of obtaining the advantage of being able to utilize full available engine horsepower under all drilling conditions. One of these schemes uses two generators, a large one and a small one, on each engine. The large generators on both engines are of the same size and the small ones also are duplicates. Under normal conditions, the two small generators operate in parallel to supply power to the drawworks motor for driving the table and for other work not requiring full rig power; the two large generators operate in parallel to supply power to the pump motor. This arrangement permits each engine to supply half of the power for the drawworks in addition to half for the pump. The total load, therefore, is divided equally between the two engines. The two large generators are used in parallel also to supply power to the drawworks motor for hoisting.

The control is so arranged that the driller can easily interchange pairs of generators between the pump motor and the drawworks motor. If the driller wants to run the pump at the same time he wants to pull heavily, as may be required under stuck-pipe conditions, he puts the pair of large generators on the drawworks motor and the pair of small generators on the pump motor. The smaller generators have ample capacity to permit the pump motor to drive the pump under these conditions. This also permits pump operation for jetting pits, mixing mud, or filling the hole when power beyond the capacity of the two small generators is required by the drawworks motor. The two large generators in parallel will usually permit pulling beyond the limit of the line strength, if not that of the derrick.

This arrangement of electrical equipment allows drilling to continue within the power capacity of one engine in case one engine is shut down for any reason. It would also permit the driller to come out of the hole

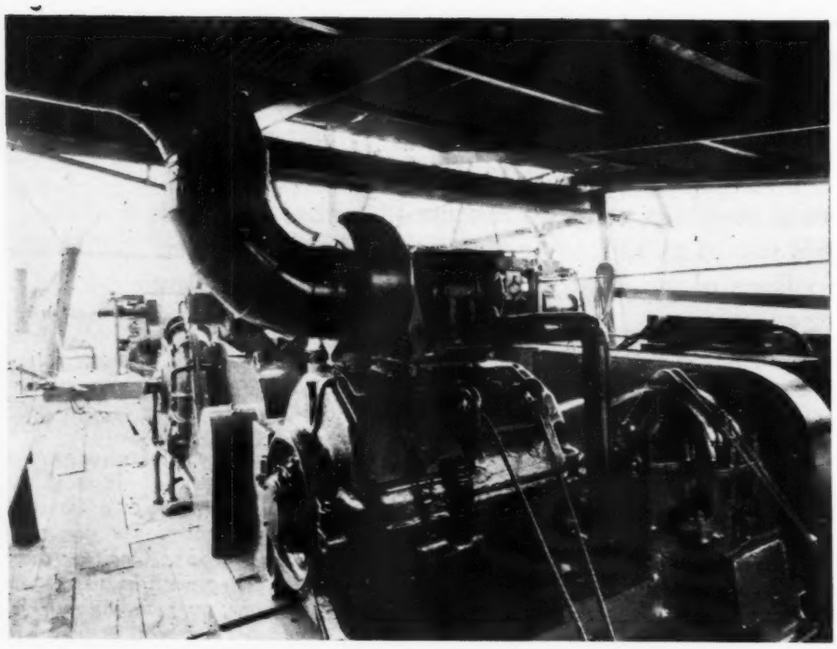


Fig. 1. Enclosed, separately ventilated, d-c. drawworks motor, 700-hp. intermittent rates

with one engine running, or he might come off bottom, rotate slowly and circulate until the engine that is down is back in service again. This arrangement provides the additional advantage of permitting a split-up of power equipment into two light rigs by the addition of a relatively small amount of additional equipment.

The other arrangement to accomplish these results consists of two generators of the same or different ratings, mounted on skids and coupled to a lineshaft arranged for V-belt drive from two or more engines. Under normal conditions, the engines drive both generators at the same time, through the V-belt drives and lineshaft. One generator supplies power to the drawworks motor for turning the table, and the second supplies power for the pump motor. Both generators operate together for hoisting service. The exciters may be coupled to the lineshaft or driven by separate engines.

The speed-torque requirements of the drawworks vary over an extremely wide range during the drilling of a well. This is especially true on a deep well if drilling trouble is experienced. During the life of any rig, drilling troubles of one kind or another are almost certain to be encountered. The designer of a rig should carefully consider the various speed-torque and power requirements of the drawworks and pumps. This should be done not only for conditions involving normal drilling operations, but also for conditions requiring fishing, pulling stuck pipe, milling, and other emergency conditions.

A rig capable of permitting proper application of power under exactly the required speed-torque conditions of the work to be done, under such emergency conditions, may be the means of saving a hole, with the contingent saving in investment of time and money, where otherwise it might be lost. Such a degree of flexibility in the application of power does save time and make easier all work that might have to be done in the drilling of a hole.

Direct-current equipment, properly applied to drilling rigs, provides a family of speed-torque characteristics of the motors that permits power to be applied effectively to both drawworks and the pumps under all required conditions.

Pulling on stuck pipe requires appreciable maneuverability and flexibility on the part of the rig. The performance permitted by a properly designed Diesel engine-d-c. rig on a stuck pipe job demonstrates the ease of power application to the work.

The drawworks motor can develop a maximum stalled or zero-speed torque of twice its full-load running torque, or even more. At the same time, the method of control permits the easy application of the stalled motor torque to the drawworks in relatively small steps from zero torque to maximum.

Usually on a stuck-pipe job, a decision is made with respect to the maximum permissible pull on the hook. Obviously this value will be within the strength of the line and also within the strength of the derrick. The maximum permissible pull decided on will usually be designated by a certain reading on the weight indicator.

When pulling on stuck pipe, the driller opens the throttle slowly and the drawworks motor exerts a gradually increasing torque, which smoothly increases the pull on the line. As this torque is being increased, the driller watches the weight indicator to make sure he does not exceed the maximum

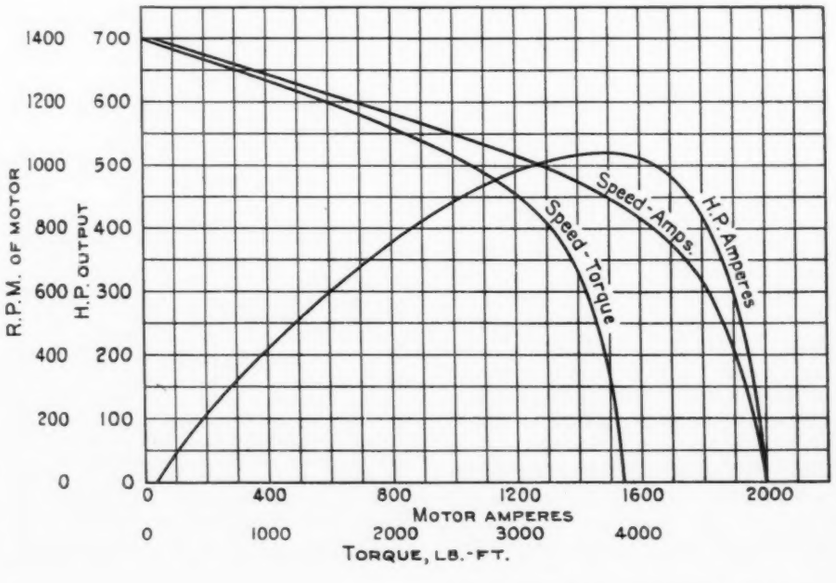


Fig. 2. Estimated characteristics of a 300-hp. drawworks motor, shunt wound, separately excited with a 90-v. field

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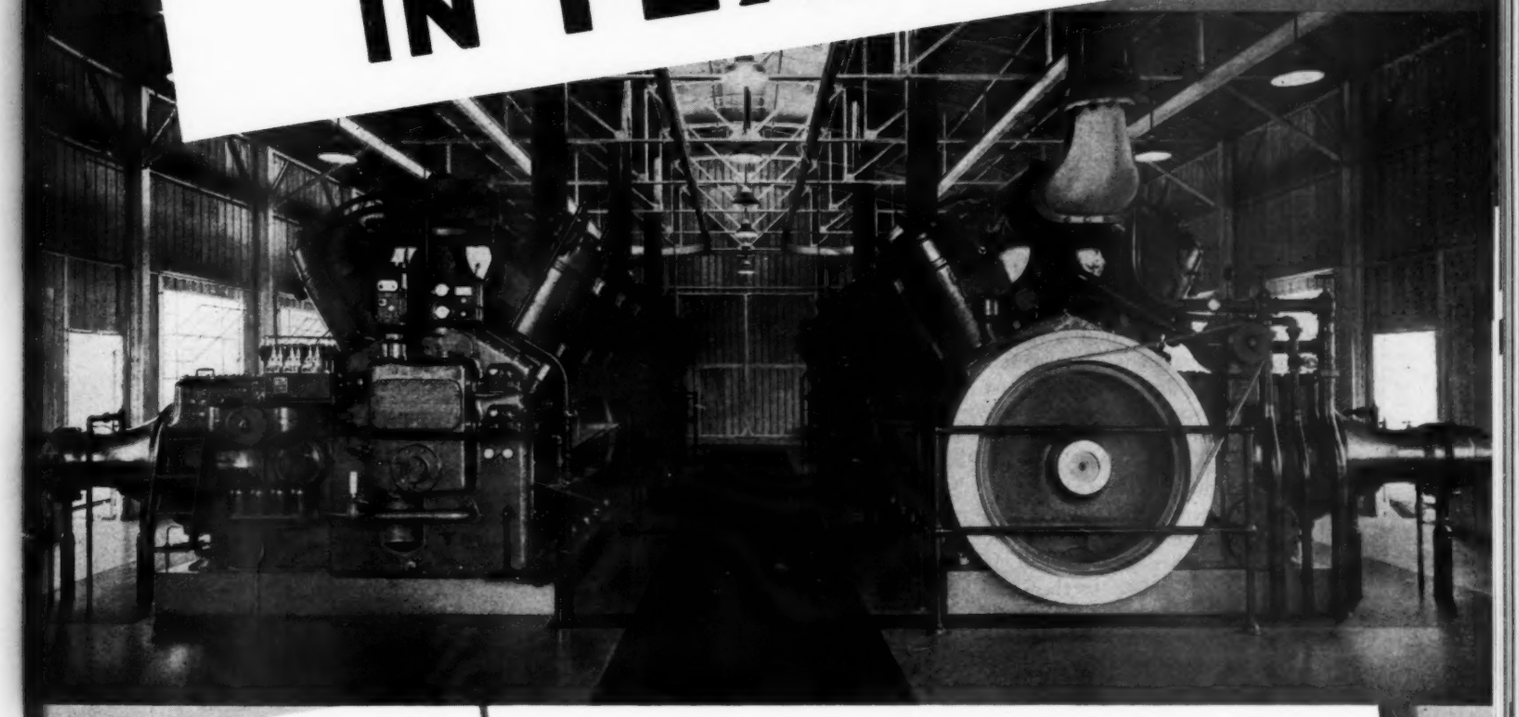

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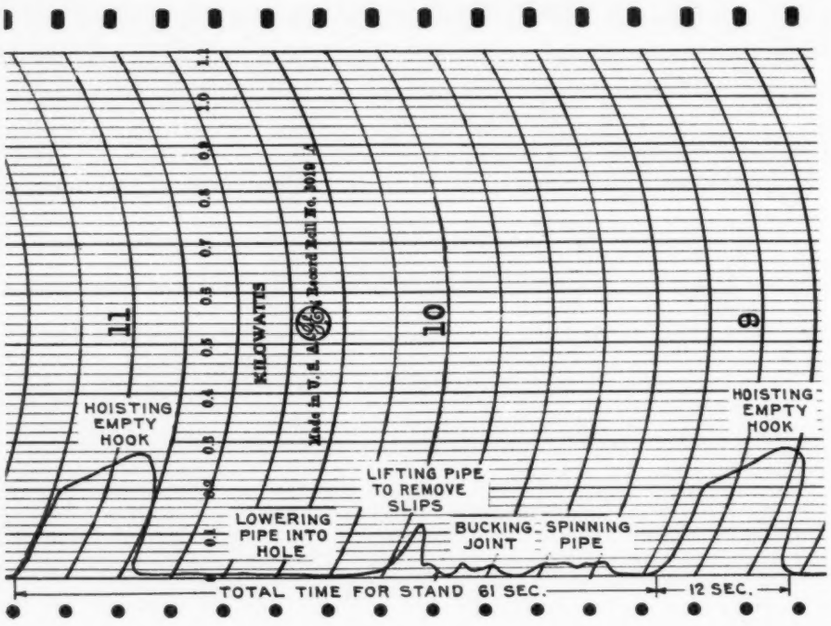

Fig. 3. Record of power consumption on a Diesel-electric rig when going back in hole with 6 lines up

pull decided on. As the pull is slowly increased, the pipe may come a few inches. At no time does a rapid increase of pull take place that requires the driller to close the throttle hurriedly. After the pipe stops moving, the driller will continue to open the throttle slowly, and gently increase the pull until the weight indicator shows the safe limit of pull has been reached. If the pipe does not move farther and the maximum allowable safe pull is being applied, the drawworks motor will stand and hold the strain without losing any of the effective pull. Under this condition, the driller will probably apply the brake, engage the table, start to circulate and rotate at creeping speed. The drawworks motor will permit very slow rotating speed of the table, and the table speed is easily controlled by the driller. At the same time, there is ample power to run the pump under these circumstances.

After rotating very slowly and circulating, the driller will take another strain on the pipe, to the maximum permissible pull. As the pipe is moved inch by inch, the driller repeats the operation until the pipe is freed. The pipe may not be freed in every case, of course, yet the easy, accurate, and flexible control of the equipment afforded by d-c. drive permits success in a high percentage of cases and usually permits the job to be done easily and in a minimum of time.

The electric equipment used on these rigs is designed and built especially for rotary drilling service. It is sturdy enough, mechanically and electrically, to withstand the severity of the application.

The motors for the drawworks and the pumps are usually of the totally enclosed, separately ventilated type. Separate motor-driven ventilating blowers are frequently mounted on top of the main motors. The blower motor may be of the totally enclosed, fan-cooled type suitable for use in explosive gaseous atmospheres. These units keep the main motors full of fresh air so that danger from explosion is minimized. The separate ventilation also permits greater output from the main motors, for a given physical size. If drilling is in a gassy territory, the air suction line can be run to a source of fresh air away from the rig, or the blower units can be moved to a remote point from the rig and fresh air blown through a duct to the main motors.

The generators are either two- or three-field machines with drooping volt-ampere characteristics. These machines have strong differential series fields together with a separately excited main field and frequently an additional self-excited shunt field. These two or three fields can be proportioned to give the desired shape of drooping volt-ampere characteristic for the generator. This will permit the proper shapes of the various characteristic curves of the drawworks and pump motors.

One of the important advantages afforded by this generator design is the fact that properly designed generators will not permit overloading of the engines, yet it is possible to get the maximum recommended power from the engines. This is inherent in the design and is entirely beyond the control of the driller. The non-overloading feature protects the engines against damage due to overloads or shock loads regardless of the manner in which the driller actuates the control. This reduces engine maintenance expense to a minimum. It also permits more engine-hour operation and less downtime.

The driller controls the motor by controlling the current in the generator shunt fields, which control the

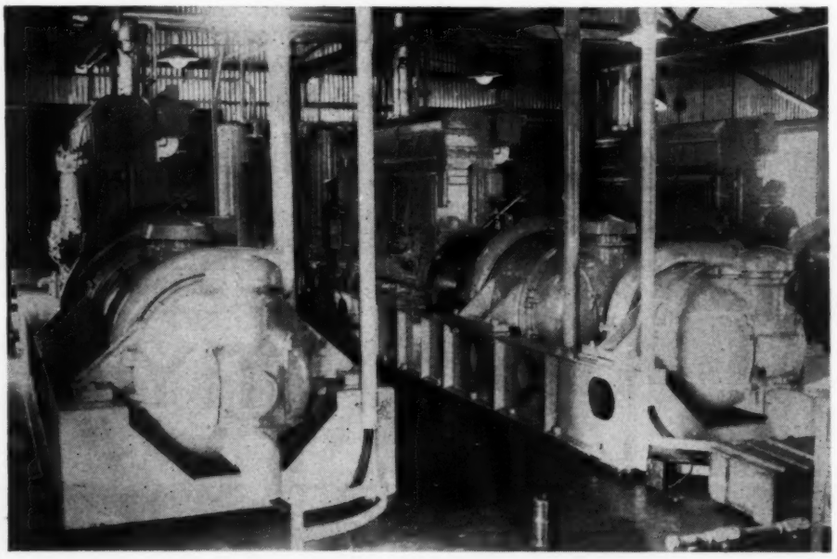

Fig. 4. Power barge for rotary drilling rig consisting of three Diesel-engine-driven generator and exciter units

Please note typical 'Starcor' performance, as shown by these job-record cards—part of a success record on job after job that merits the Oil Man's consideration.

W 2401

FIELD: East Texas
TYPE OF JOB: Squeeze, through ten 3/4" perforations
DEPTH OF WELL: 3588 ft.
MAX. TEMP.: No recordings
SLURRY WEIGHT: 16¼ lb. per gal.
CEMENT USED: 'Starcor', 100 sacks
MIXING TIME: 8 min.
PUMPING-DOWN TIME: 52 min.
MAX. PUMP. PRESSURE: 3100 lb.
REMARKS: 6 sacks of 'Starcor' were pumped out into formation under 3100 lb. pressure. Circulation was reversed and unused cement pumped out. Even under extreme pressure, 'Starcor' performed perfectly, as usual.

ST 1737

FIELD: Big Lake, Texas
TYPE OF JOB: Casing, 2825' of 10-3/4", in 13-7/8" hole
DEPTH OF WELL: 3000 ft.
MAX. TEMP.: No bomb run — temperatures moderate
SLURRY WEIGHT: 15½ lb. per gal.
CEMENT USED: 'Incor', 2000 sacks
REMARKS: This pipe was cemented from top to bottom. Well was projected as an 8600' test; a good cement job was needed. Whipping of drill stem in making nearly 6000' of hole under the string meant considerable strain on the pipe. Pumping 2000 sacks of 'Incor' under these conditions indicates an easy-flowing slurry, sure enough.

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Use 'Starcor'* for deep wells—greater length and ease of pumpability at high temperatures. Use 'Incor'* for wells of moderate depth, earlier drill out, wells on production quicker. Oil-well cements, kept abreast of the constantly changing needs of the oil industry's rapid progress. *Reg. U. S. Pat. Off.

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generator voltages. The motors are usually separately excited; shunt motors and their excitation are on continuously while the rig is in operation. The motor armature leads are connected to the generator armature leads. Consequently, if the driller puts the controller in the neutral position, the generator shunt-field circuits are opened, the generator voltage is zero, and the motor stops. When he moves the controller, he closes the generator field circuit, either forward or reverse, and gradually increases the generator field strength, which increases the generator voltage, which, in turn, causes the motor to start to run and to develop more power. The complete control is obtained by employing small currents in field circuits without any interruption of the main current-carrying circuits. This means easy control, long life, and low maintenance of current-carrying control parts.

Fig. 2 shows a typical set of characteristics of a 300-hp., 275-v., drawworks motor receiving energy from a generator with a full generator field for two 240-hp. engines. Usually 20 or more field-control points forward and reverse are provided. With such control, a corresponding number of each of the above characteristics is provided between those shown, which represent the full generator field characteristics, and zero, the point at which the field circuits are opened. These characteristics, with the ease of complete control, make possible smooth acceleration under all conditions of operation and provide a flexibility of torque-speed application of power to the work to be done that insures fast, safe drilling under all conditions.

These characteristics also provide a fast empty-hook speed, automatically. This makes a rig snappy, and the crew usually works faster and is happier on the snappy rig.

It is known, of course, that the time used in manipulating the empty hook is only a small percentage of the total drilling time. This indicates that fast empty-hook speed is relatively unimportant. It has been found, however, that fast empty-hook speed does save drilling time due to the faster actions of the crew as well as to the faster hook speed itself.

Fig. 3 shows a section of a curve from a wattmeter chart taken on the drawworks motor of a Diesel-electric rig when going back into the hole with six lines up. A total of fifty-seven 90-ft. stands of 6-in. drill pipe was put back in the hole in one hour. The average time per stand was slightly over one minute.

It is interesting to note the time used and the power required in the various operations when going back into the hole. The chart shows that, from the time the driller started to open the throttle to raise the empty hook, until the elevators coasted into the pipe, a total of 12 seconds elapsed. The power was on the drawworks motor for slightly over 11 seconds from the time the driller began to open the throttle until he closed it. The power delivered by the generators reached a peak of 350 kw. during the period of acceleration of the empty blocks. At the time the driller started to close the throttle, the generators were delivering approximately 250 kw. The drawworks motor output under these two conditions was approximately 390 hp. and 280 hp., respectively.

Following is a table of results given by the chart:

Operation	Hoisting empty hook	Preparing to spin pipe	Spinning pipe	Bucking joint	Picking-up to remove slips	Lowering pipe into hole	Miscellaneous	Total
Time, sec.....	12	6.25	5	6.25	3.75	22	7	62.25
Generator peak output, kw.....	350	.....	50	50	135	.....	.....	.....
Drawworks motor output, hp.....	423	.....	56	56	150	.....	.....	.....

The d-c. generator-voltage-controlled electrical equipment used with internal-combustion engines provides the following advantages on full-electric rigs:

1. Complete maneuverability and flexibility of rig operation is provided under all conditions of drilling or emergency operation.

2. The drilling load is divided automatically between the two or more engines.

3. The maximum output of engines is limited automatically to a safe value by proper generator design. This reduces engine maintenance and downtime.

4. The power is smoothly and gradually applied to the load, and high torque at very low speed is afforded by proper generator and motor design. These characteristics permit easy starting of the load off bottom and reduce shock loads throughout the rig from hook to engines and thus reduce maintenance on the entire rig.

5. The maximum output of both engines can be fully, easily, and safely used for hoisting service.

6. High empty-hook speed is provided automatically by inherent generator design. This keeps the crew on its toes and reduces total time required for going back into the hole.

7. The mud pump motor will slow down and stall in case of excessive pump pressures due to plugged bit or pipe. This may save both power and fluid ends of the pump.

8. Pump speed can be easily controlled over a wide range.

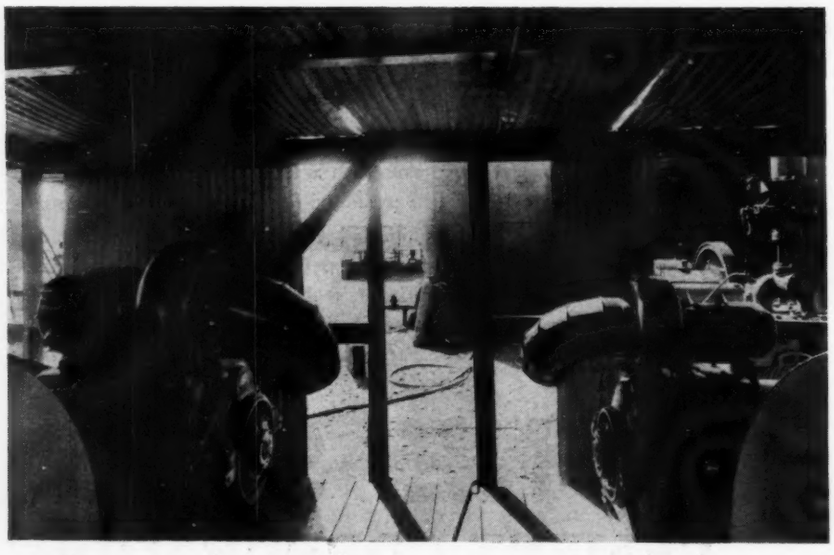

Fig. 5. Two d-c., enclosed, separately ventilated mud pump motors on a rotary drilling rig, Diesel-electric powered

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Larkin Casing Centralizers are simple, fool-proof, dependable in every way—just as are Larkin Float Shoes, Tubing Heads, Spiders, Bull Plugs, Swage Nipples, Casing Heads, Guide Shoes, Float Collars, Casing Clamps, Packers, and Sand Pumps. Larkin Casing Centralizers consist simply of two steel rings to which four heavy-duty heat-treated, arched steel springs 18″ long are double riveted. Springs have ample tension and more-than-required strength. Set screws on lower ring secure centralizer at any desired point on the string. For a lasting, water-tight, gas-proof seal at bottom; or for a series of above-pay cementings when producing from strings with multiple perforations, rely on Larkin Centralizers to keep the casing in the center of the hole.

FIG. 428

LARKIN FIG. 428

Bakelite Ball-Valve Float Shoe

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9. The engines operate at constant speed regardless of the speed-torque requirements of the load. This permits convenient rig operation and also reduces maintenance.

10. Engine speed can be reduced when drilling conditions do not require full power output of the engines at full speed and still provide all of the rig maneuverability and flexibility of control as provided at full-engine speed.

11. Low fuel consumption.

12. Electric energy available for lighting and auxiliaries from exciters, eliminating necessity for running small separate engine-generator for this purpose.

13. Closed cooling-water system can be used with very little makeup water required.

14. Engines and generators can be situated at any convenient place around the rig.

The second deepest hole in the world, drilled near Elk City, Oklahoma, to a depth of 14,582 ft., was drilled with a Diesel full-electric rig.

This rig used two main Diesel engines, each rated 300 hp., continuous, 375-hp. peak for hoisting. Each engine is direct-connected to two generators, one rated 140 kw., continuous, and the other rated 50 kw., but capable of carrying 60 kw., continuous. On top of each of the smaller generators is mounted one 25-kw. exciter. The exciters are V-belt-driven from the generator shafts.

Mounted on the same skids with each engine and generator set are two radiators, one for engine circulating water and the other for lubricating oil. Each radiator is provided with a fan and each fan is driven by a 10-hp. motor provided with speed control.

The complete self-contained power units, all mounted on skids, are provided with housings. The sides of these housings when raised, together with the roofs, provide shelter for the equipment and operator.

The two 140-kw. generators normally operate in parallel and provide power to one of two motor-driven mud pumps. The two smaller generators normally operate in parallel and supply power to the drawworks motor for turning the table or other relatively light work. A master switch at the drawworks post permits the driller to interchange easily the two pairs of generators so that the two large ones are connected to the drawworks motor and the two small ones are connected to the pump motor, thus permitting the two large generators to supply power for hoisting and the two smaller ones to drive the pump if it is necessary to pump while hoisting.

In addition to the two main power units, there is an auxiliary unit consisting of a smaller engine driving a duplicate of the two main small generators. This machine also has a separate 15-kw. exciter. The control is so arranged that the auxiliary generator can be operated independently of the other equipment for driving one of the mud pumps for mixing mud, jetting pits, or any other light work desired.

This generator can also be operated in parallel with either or both of the small main generators. This provides additional power for operating the table if this is necessary for reaming or for table speeds higher than normal. Also, if one main engine is down for any reason, approximately 125-hp. output of the drawworks motor is still available for the table and the single large generator can supply enough power to allow the pump motor to deliver approximately 160 hp. to the pump. The auxiliary exciter and the main exciter together can supply the total power for all excitation and auxiliary load, including the one remaining 10-hp. motor driving radiator fans, the 5-hp. motor-driven blowers on the drawworks motor and on the one pump motor, the shale-shaker motor, the washdown pump motor, and the rig lighting. Under these conditions, drilling at a reduced rate can proceed.

The auxiliary generator can also be operated in parallel with either or both of the two large main generators. This permits the power of the auxiliary engine to be added to either or both of the two main engines for hoisting, if that is required. It also permits the power of the auxiliary generator to be added to that of the two main generators for supplying power for operating both pumps compounded, if that is desired.

The motors on the drawworks and pumps of this rig are enclosed, separately ventilated machines. Each has a separate totally enclosed motor-driven blower mounted on top to provide for ventilation.

The control on the derrick floor is oil-immersed and is of a type that reduces hazard in gaseous locations. This control is conveniently situated so the driller may easily control the rig. The main control unit is mounted on skids and is usually placed near the engine.

Parallel operation of generators of multi-unit rigs such as this provides several advantages:

1. Generators of different sizes can be operated in parallel and they will divide load in proportion to their ratings. This permits the easy addition of another engine generator to a rig. It also makes it possible to use two generators of different sizes on a rig, say, a 150-kw. generator for the table load and a 300-kw. generator for the pump load; yet the two can operate successfully in parallel for hoisting and they will divide the load in proportion to their ratings.

2. No matter how many generators are used on a rig, it can be arranged so

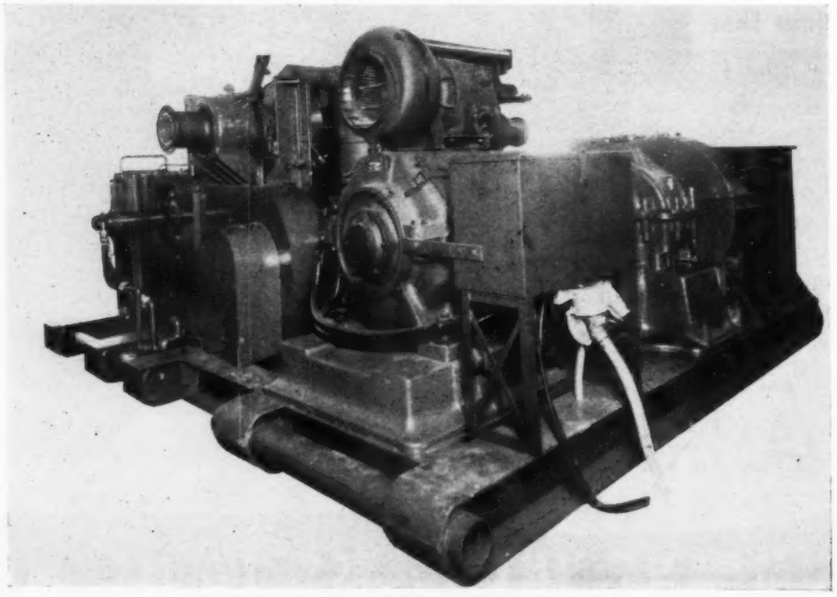
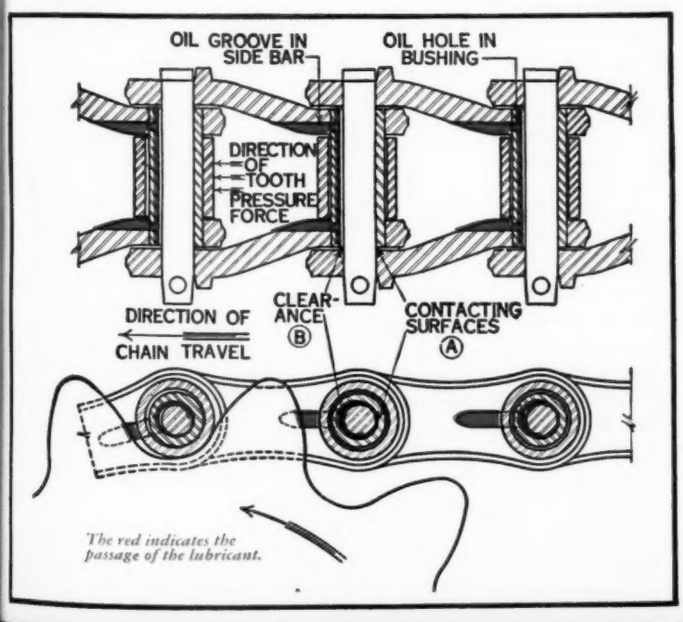


Fig. 6. Enclosed 400-hp. motor connected to unitized drawworks. Note the cable receptacles underneath the terminal box

Again LINK-BELT Rolls Ahead

IN CHAIN IMPROVEMENTS THIS TIME WITH THE Self-Lubricating 3-BAR HYPER

The patented oil-grooved side bar permits free entry of oil to chain joint and bearings. Note, in the sketch below, how the forces of tooth pressure and chain load act in opposite directions, making the bushing and pin contact along the line marked "A". All clearance between pin and inside of bushing is on the opposite side, along the line marked "B", permitting the lubricant to flow freely into the chain joint.


OIL GROOVE IN SIDE BAR
OIL HOLE IN BUSHING
DIRECTION OF TOOTH PRESSURE FORCE
DIRECTION OF CHAIN TRAVEL
CLEARANCE (B)
CONTACTING SURFACES (A)
The red indicates the passage of the lubricant.

Introduction of Link-Belt's Self-Lubricating 3-Bar HYPER Chain marks another remarkable step in oil country chain improvement. It is SS-124, a drop forged sidebar, A.P.I.4 rotary chain, with an ultimate strength of 170,000 pounds. It is significant to chain users that this is another Link-Belt improvement . . . for Link-Belt not only pioneered the art of chain making but pioneered oil industry chain with the coming of rotary drilling, and has continuously made chain improvements as drilling speeds, depths and loads have increased. This major improvement means added durability to an already great chain having world-wide popularity through years of successful performance.

For more details ask for Folder No. 1854.

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LINK-BELT CHAINS

THE CHOICE OF EXPERIENCED DRILLERS

Fig. 7. Two a-c. drawworks motors each rated 125 hp., 900 r.p.m., operating in parallel

that they can all be effectively used for hoisting without exceeding 600 volts, the usual rating of wire and cable insulation used on rigs.

3. A generator of the type used here, when operating in parallel with others, will not reverse rotation under motor action if the engine driving it shuts down because of failure of a fuel line or for any other reason. Under this condition, the generator will run as a motor in the same direction and will draw power from the other generator or generators with which it is paralleled, but no harm will be done to any equipment.

4. Several generators operating in parallel can be controlled by a single field controller.

The advantages of electric operation when internal-combustion engines supply power for a rig, have been widely recognized. These advantages are especially important for drawworks operation. The appreciation of this fact led to the development of the combination Diesel electric-mechanical rig for medium-depth drilling. It provides for electric operation of the drawworks with all the advantages of flexibility and ease of control afforded in the drawworks of a full-electric rig. The pump, however, is driven mechanically from the engines.

The chief advantages provided by this type of rig are:

1. Complete flexibility of drawworks operation afforded.

2. Relatively low first cost.

3. Loss in transmission to pump is low, which permits greater percentage of available engine horsepower for pump use.

4. Main control unit can be mounted on same skids with generator, which permits permanent wiring between generator, exciter, and main control unit. This simplifies wiring during rigging-up.

5. Placement of engine not affected by location of the derrick.

6. Auxiliaries can be operated electrically from exciter, which eliminates necessity of running a small separate engine generator for lights and auxiliaries.

Rigs of this kind generally use two internal-combustion engines, which operate in parallel mechanically. The two engines together drive the pump, the drawworks generator, and exciter. This arrangement permits full engine horsepower to be divided between the pump and the drawworks. The maximum engine horsepower is available for hoisting, but the protection against overload, and flexibility of drawworks operation are afforded to the same extent as on the full-electric rig. As the pump can be driven mechanically while the drawworks motor is running, this rig can operate under certain emergency conditions nearly as well as the full-electric rig.

The disadvantages as compared with the full-electric rig are:

1. Less flexible pump operation.

2. Engines must be placed close to the slush pit and therefore close to the rig.

3. Mechanical operation of engines in parallel usually requires additional skill on the part of the engine operator to assure proper engine performance under all conditions of operation.

Several rigs of this type have been operating successfully for some two years or more and have given very successful operation in the field.

In order to simplify wiring electric rigs and to reduce rigging-up time, cables with plugs and receptacles have been used. On one rig using electric equipment, all of the control wiring, auxiliaries, and motor-field circuits have been comprised of cable with plugs and receptacles. The plugs and receptacles are polarized so that they can not be put together wrong.

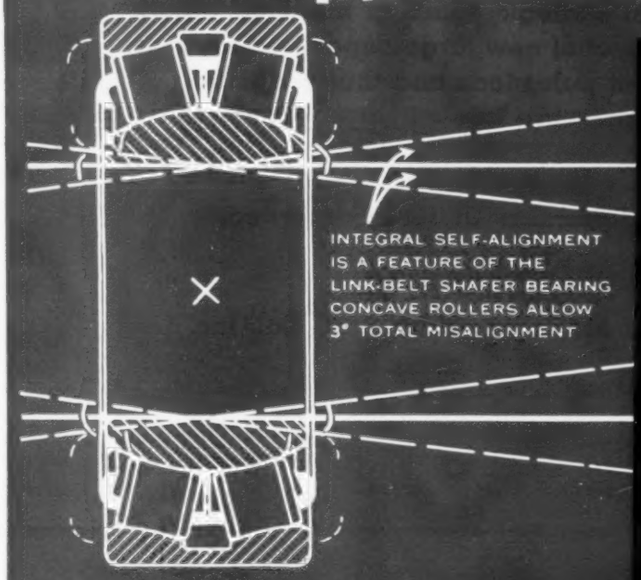
This means that when the equipment is in position, the crew can easily plug-in both ends of the cables at the proper places. The two armature leads to the motor are not arranged with plugs because of the size required, but as there are only two armature leads for a motor, there is no real difficulty in making these connections and no harm can be done if the leads are interchanged. Crossing of these leads merely causes the motor to run in the opposite direction, and if the direction of rotation is not as the driller wants it, corresponding to the direction in which he opens the throttle, it is very easy to interchange the two armature leads at the motor terminals to get the direction of rotation he wants.

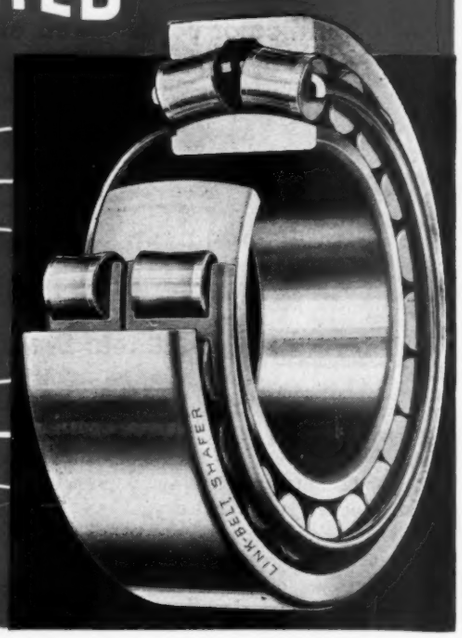
Alternating-current equipment has been most widely used on drilling rigs when electric energy from a power company is available. Slip-ring induction motors with control suitable for the application have been used and have done the work to the satisfaction of the drillers and crews who have used this type of equipment.

Alternating-current generators have also been used with internal-combustion engines to supply power to rigs using a-c. motors. It is generally conceded, however, that if internal-combustion engines are to be used with electrical equipment on a rig when new power equipment is to be purchased, the advantages afforded by d-c. equipment warrant its use.

Developments of Diesel-electric equipment for drilling rigs are proceeding continually. Larger rigs are being designed and new arrangements of equipment are being considered. Undoubtedly, Diesel-electric-powered rigs for deeper drilling will play an increasingly important role.

SELF-CONTAINED ... SELF-ALIGNING PRE-ADJUSTED





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LINK-BELT SHAFER ROLLER BEARINGS

Piping and Header Design to Minimize Pressure Drop

Indicator cards taken at strategic points in manifold piping are used to study the effect of new large capacity discharge lines on damping-out pulsations and thus reducing pressure loss

By C. S. WORLEY
Engineer, Consolidated Gas Utilities Corporation
and
D. K. HUTCHCRAFT
Mid-Continent Sales Manager, Clark Bros. Co., Inc.

NO designing engineer would think of authorizing the purchase of engines and compressors for a gas compressing station without first having satisfied himself that the engines selected would develop their rated horsepower, and that the compressors would meet the desired pressure requirements. This is equally important in the selection of all auxiliary units.

Notwithstanding the precautions taken in selecting these items of equipment, it is probable that sufficient study has not been given to the proper design of piping and headers to handle the gas efficiently and economically after it has been compressed. Here, it seems, a great deal of generated energy is being dissipated, which results in excessive pressure drop through the plant.

Particular attention was given to this phase of the work prior to building a 1200-hp. gas compressing plant for Consolidated Gas Utilities Corporation, near Shamrock, Texas, during the late summer of 1939.

In making a series of tests and observations at some of this company's stations already in service, as well as in a number of other plants, it was surprising to note the excessive overall drop in pressure. In some cases it showed in excess of 10 percent of the initial discharge pressure. These observations were all made in modern, and apparently well-designed stations. It seemed quite obvious that the fault lay in improper design of piping and headers, with possibly some rather excessive drop through gas coolers.

Certain fundamental errors in previous installations had to be recognized and overcome.

It appeared, from the observations and the subsequent study made, that gas discharged from higher-speed compressors showed a greater pressure drop than gas delivered from lower-speed units. This was no doubt due to a greater turbulence having been set up by the increased action of compressor pistons and valves.

It takes time and reservoir capacity to adjust these pulsations and vibrations. If this is not accomplished before the gas reaches the discharge lines, it will result in greater friction in the pipe line, which, in turn, results in in-

C. S. WORLEY

attended the Engineering School of Oklahoma A. & M. College, Stillwater, 1902-1905—Began work in the oil and gas industry with the Henderson Gasoline Company, Nowata, Oklahoma, in 1914—Went with Jordan, Laney and Nickel, contracting engineers, Bartlesville, Oklahoma, in 1917—Organized firm of Worley, Johns and Bowman in 1919, operating in Kansas, Oklahoma, and Texas—Was assistant superintendent of the Gas Lift Department, Twin State Oil Company (Sun company), 1927 to May, 1929—Since June, 1929, has been an engineer for the Consolidated Gas Utilities Corporation, Oklahoma City, Oklahoma, being in charge of station construction and operation, and general engineering work—Is also purchasing agent for the company—Is registered as a professional engineer in Oklahoma and Texas—Member of Oklahoma Society of Professional Engineers, National Society of Professional Engineers, and National Association of Purchasing Agents.

D. K. HUTCHCRAFT

has been connected with the sales department of Clark Bros. Co., Inc., for 14 years, and for the last 8 years has been Mid-Continent sales manager, having his headquarters at Tulsa, Oklahoma—Has designed and supervised the construction of booster stations and other installations pertaining to compressors; specialized in gas-lift work during the Seminole, Oklahoma, boom—He installed the first gas-lift recycling plant in the Mid-Continent and has assisted in many of the newer applications wherein compressed gas is used by the oil industry—Prior to his present connection he was manager of the Tulsa office of the Chicago Pneumatic Tool Company and before that was vice-president and chief engineer of the Indiana Air Pump Company—Holds professional engineer's license in the states of Indiana and Oklahoma.

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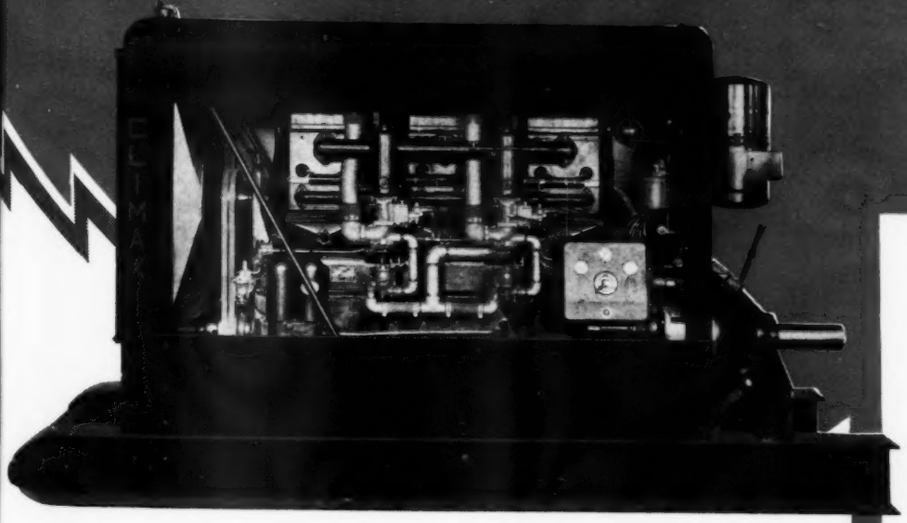

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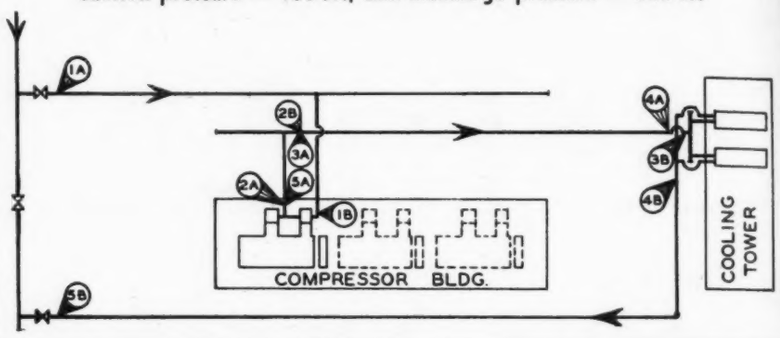
creased pressure until these vibrations and pulsations are absorbed. If this can be accomplished in a large reservoir, before the gas reaches the common discharge line, it has smooth passage in the line; otherwise the pulsations are multiplied and intensified as several compressor cylinder discharge into a common line, and the back pressure, due to this increased friction, places an unnecessary load on the engines and compressors. As the pulsations are absorbed, there is obviously a drop in pressure. This absorption should be accomplished as near the compressor as possible.

The particular plant in question was installed on a 14-in. main gas transmission line, and was designed to boost pressure from an intake varying from 110 to 160 lb. gauge, to a discharge of 300 to 350 lb. At these pressures, and based on a maximum daily delivery of approximately 10,000,000 cu. ft. per day per 400-hp. unit, it was determined that each discharge line, before entering the header, should have a reservoir capacity of the equivalent of 30 ft. of 10-in. pipe.

Having in mind, however, the idea of keeping the entire plant as compact and streamlined as possible, it was decided to use a short 14-in. header connecting the 6-in. down-pipes from the two compressor cylinders on each unit, and to maintain the same size (14-in.) discharge line a short distance outside the compressor building, and there swage to 8-in., for the installation of valves, before connecting into the discharge header. This increase in diameter of the discharge line made it possible to create the desired reservoir capacity in about 14 ft. of 14-in., and 6 ft. of 8-in. pipe. Approximately 100 ft. of 14-in. line was required from the discharge header to the atmospheric cooling coils, with 250 ft. of 14-in. from the outlet of the gas coolers to the master discharge valve connecting with the main line.

This installation has proved extremely satisfactory, and has resulted in a much less overall pressure drop than exists in any of the plants investigated in advance of this undertaking, under similar pressure conditions. It has resulted in the passage of about 5 percent more gas through the plant, at given pressures, than would otherwise have been anticipated.

Letters indicate points at which indicator pressure readings were taken. Thus, Card 1 taken at 1A and 1B, volume 29,000,000 cu. ft. per day: suction pressure = 130 lb., and discharge pressure = 300 lb.



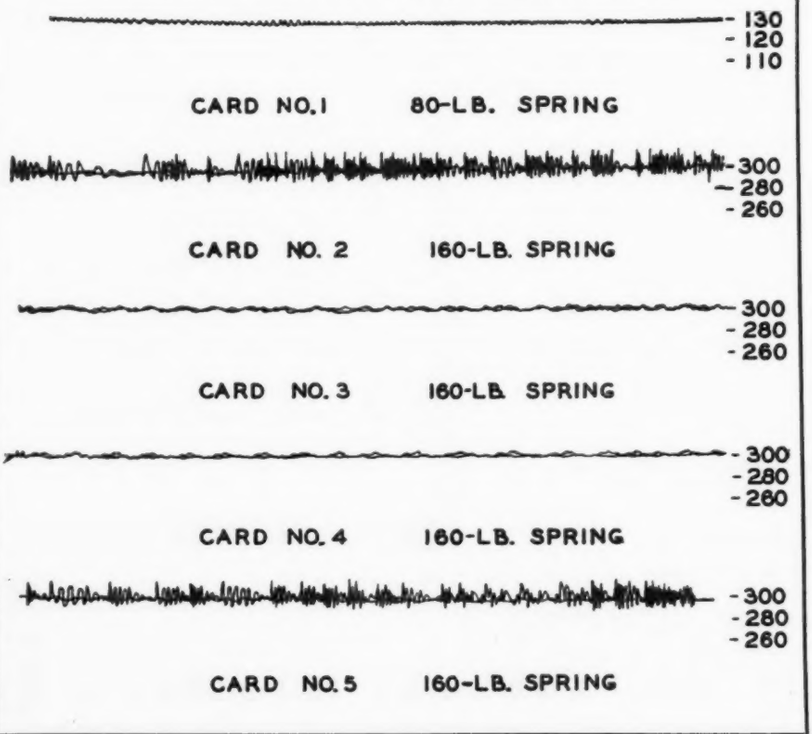
In order to get an accurate picture of the pressures, and to register the drop between various points in the system, several ½-in. connections were provided in the piping, to which an indicator could be readily attached. By indicator tests it was possible to obtain not only the accurate pressures, but also to record pulsations due to piston and valve action near the compressors and to determine at what point these pulsations were absorbed. A card made at one point was then superimposed by a second reading made at some remote point in the system. The relative pressures at the two points recorded on the same card give a true comparison.

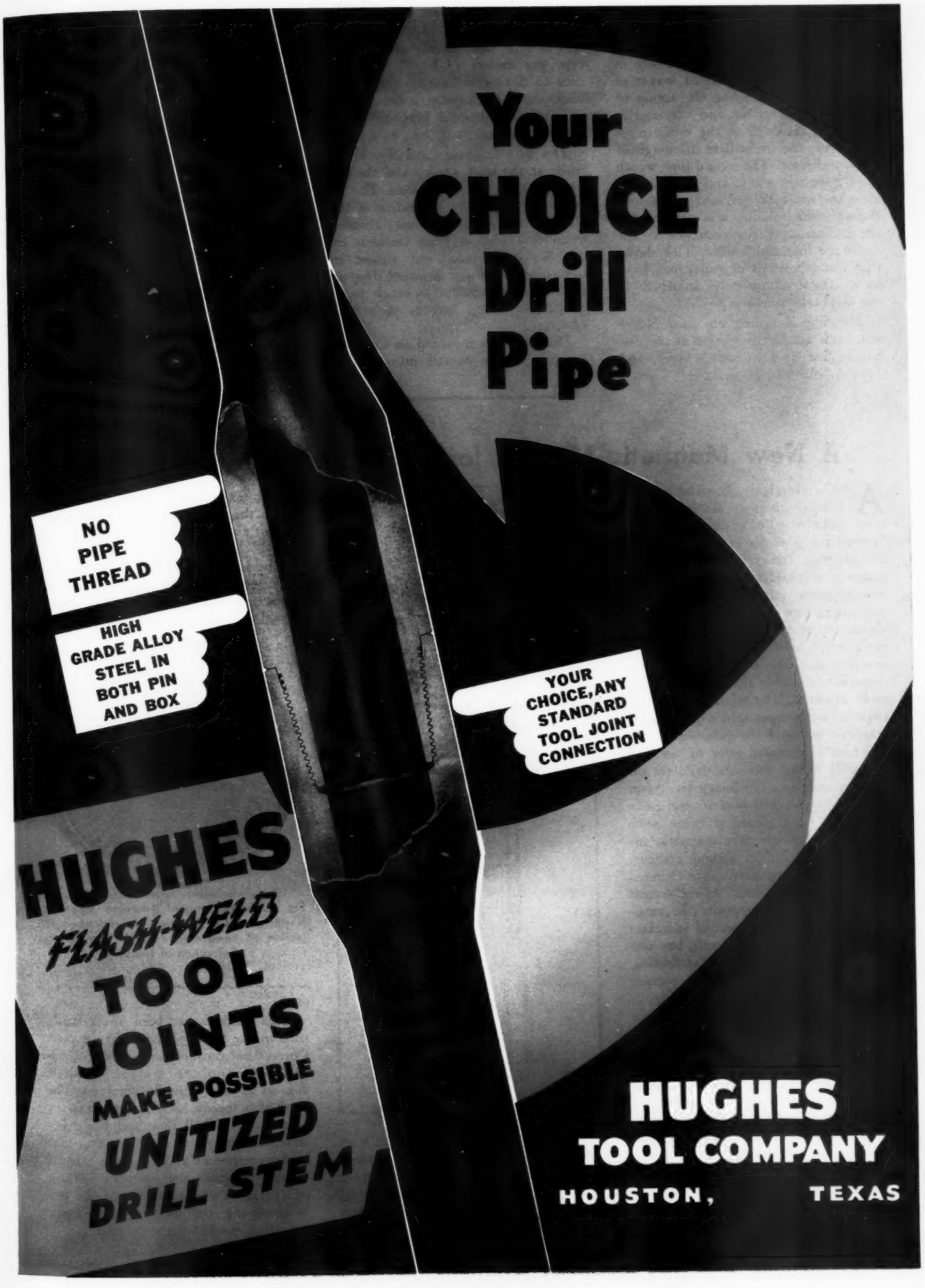
During these tests, intake and discharge pressures were maintained absolutely constant at the gauge board in the compressor room—130-lb. intake and 300-lb. discharge—delivering at the rate of 29,000,000 cu. ft. per day, on an 8-oz. base.

The cards obtained are reproduced in the accompanying illustrations, and a general diagram of the plant piping is shown on which points, with identifying designations, are indicated to show where the several tests were made.

By closely inspecting the upper markings on Card No. 1, it will be observed that there is a thin, wavy line, which is bisected by a fairly straight line. The straight line was procured with the indicator at the intake master gate connection (1-A), whereas the wavy line was recorded at the intake riser at the compressor cylinder (1-B). The difference between the two readings, if it could be measured, represents the pressure drop from the main line intake connection to the compressor cylinder. This card was made with an 80-lb. spring. All other cards were taken with a 160-lb. spring.

Indicator cards to record pressures and pulsations

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TOOL JOINT
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Observation of Card No. 2 will disclose two sets of lines, one of which indicates a wide range of pressure in a succession of accentuated waves or oscillations, representing the action of the compressor piston and valves; this chart was recorded at the down-pipes at (2-A), the immediate discharge of the compressor. The second line, which is only slightly wavy, and which intersects the more exaggerated line almost through the middle, was taken with the indicator at the junction of the discharge line and header. This shows that the vibrations or pulsations have been almost completely absorbed in the discharge reservoir.

The first recording on Card No. 3 was made at the connection of the discharge line and header (3-A), and the second line was procured on the riser to the inlet of the atmospheric-type gas coolers (3-B). It is impossible to distinguish between these two lines, which, of course, indicates there is insufficient drop in pressure to register in the records at these two points.

The recordings on Card No. 4 were made at the inlet (4-A) and the outlet (4-B) of the gas coolers. The line recorded at the outlet indicates that the vibrations not previously absorbed were eliminated in these coils, as this line has straightened out almost entirely and the slight pressure drop indicated is perhaps due as much to the temperature drop here as to reduced vibration.

The two lines recorded on Card No. 5 represent the overall pressure drop from the compressor discharge (5-A) through the piping, header, and gas coolers, to the discharge master gate connection at the main line (5-B). The accentuated wavy line, of course, was registered at the compressor discharge; the comparatively straight line was obtained at the remote point. This recorded pressure drop, with a temperature reduction of 65° F. included, indicates loss in pressure through the entire system of only slightly more than 3 lb.

In view of the above results, and the observations made at a number of other plants where the overall drop in pressure was much greater, it seems that material improvement in efficiency and economy might be effected by giving careful study of piping design.

P 429.22

A New Magnetic Method for Orienting Deflecting Tools

A NEW method of orienting deflecting tools at the bottom of bore holes has been developed by Sperry-Sun Well Surveying Company, Philadelphia, Pennsylvania. The orientation is accomplished by the use of a non-magnetic sub (shown in Fig. 1), containing two small magnets and provision for seating a directional magnetic single shot instrument. The sub is arranged in the drill-string assembly immediately above the deflecting tool to be oriented. The relative azimuthal angle between the magnets of the non-magnetic sub and the direction of the tool face is measured prior to lowering the drill string into the hole in the same manner as an ordinary bit. After the tool has reached bottom and prior to setting it, a record is taken with a directional single shot magnetic instrument in which a second compass unit has been temporarily interchanged for the inclination unit. As the second compass is directly opposite the magnets in the sub, this record indicates not only the magnetic North, but also the relative position of the deflecting tool to the magnetic North. A picture of the sample record is shown in Fig. 2. The magnetic North, shown by the letter N and the position of the deflecting tool, W-73-S, is indicated by the intersection of the white needle with the round black circle. The drill pipe is then rotated to bring the deflecting tool into the desired position, and another single shot record is made to check on the final position of the deflecting tool.

In holes that have an inclination of more than 3 deg., and in which the inclination and the direction of the hole

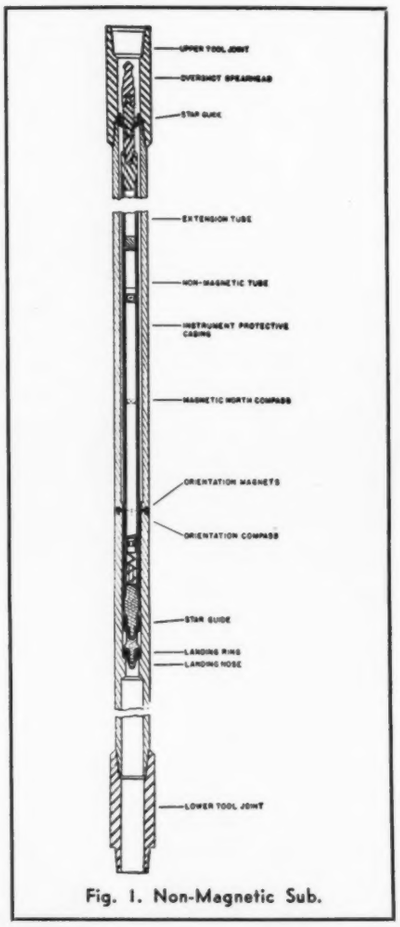

Fig. 1. Non-Magnetic Sub.

at the point where the deflection is to take place is known from a previous survey, a short magnetic sub, provided with four magnets and a directional magnetic single shot with one compass and an inclination unit, is used. The record taken inside the magnetic sub shows the inclination and relative position of the deflecting tool to the direction of the inclination. As the direction of the inclination is known from the previous survey, the direction of the deflecting tool can be easily determined.

Fig. 2. Sample record (showing magnetic North, as well as direction of deflecting tool section of needle with circle indicating direction of tool).

This method has been successfully used in the field for more than a year. Correct bottom-hole orientation of the deflecting tool to within one-half deg. in azimuth can be obtained. The method is speedy, as it is not necessary to orient the drill pipe and the drill-string assembly can be lowered as fast as the equipment and the crew permit. It also provides the operator with a photographic check picture of the position of the tool prior to starting the deflecting work.

Wilson SETS FAST DRILLING PACE WITH NEW TYPE Friction Clutch!

HERE is one of the many outstanding features which have made Wilson Rigs world-wide successes.

While new and revolutionary in principle and design, the Wilson Friction Clutch has been thoroughly tested and proved successful by 2½ years actual field service. As a result of this practical experience, users as well as the manufacturer definitely know that this clutch is by far the most satisfactory and efficient clutch ever installed on a rotary power draw works.

Briefly, here are the high points of the Wilson New Type Friction Clutch:

1. Has 5½ times the holding power of any other clutch.
2. Circulating water-cooling in space between brake ring and clutch ring—keeps both brake and clutch cool, and effectively prevents heating of clutch surface.
3. Smooth, easy to engage. It will not grab or stick.
4. Long life replaceable block type friction lining. The three clutch shoes expand equally on both ends of all shoes, thus obtaining maximum wear of friction lining.
5. Clutch spider can be locked to drum, in event of trouble with friction clutch, simply by installing three bolts. The clutch then becomes inoperative, leaving a jaw clutch on the counter shaft which controls the drum in emergency, or at any time the Friction Clutch is not needed.
6. Single adjustment—adjusts all shoes equally and simultaneously from any one of three places. Adjustment for wear easily and quickly made.

Wilson Sets the Pace!

BOLT HOLES FOR LOCKING SPIDER TO DRUM (SEE POINT 5)
HARDENED AND GROUND STEEL BRAKE RINGS
WATER INLET AND OUTLET
SINGLE POINT ADJUSTMENT FROM ANY OF THESE 3 POINTS.
SHOES EXPAND ON BOTH ENDS - GIVING MAXIMUM HOLDING POWER AND LONGEST WEARING LIFE.
OILLESS BEARINGS REQUIRE NO LUBRICATION
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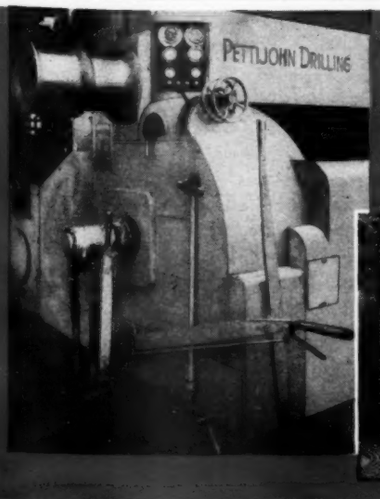
BRAKE RING
COUNTERWEIGHTS BALANCE AGAINST CENTRIFUGAL FORCE
SPROCKET BOLTS TO THIS SPIDER
PIPE FOR CIRCULATING COOLING WATER
WATER COOLING SPACE BETWEEN RINGS COOLS BOTH BRAKE AND CLUTCH
HARDENED CAM
BALL BEARING SHIFTER YOKE
5/16" REGULAR BRAKE LINING

• 5 TIMES THE HOLDING POWER **• CIRCULATING WATER COOLED** **• INSTANT ADJUSTMENT**

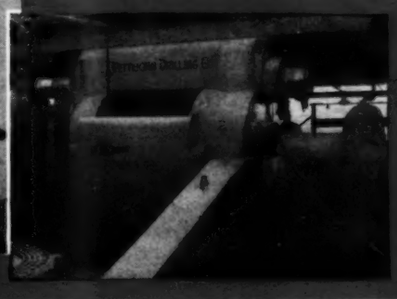
• Over five times the holding power is provided by Wilson Friction Clutch.

• New and proved successful Circulating Water-Cooling System cools both *brake* and *clutch.*

• All shoes are adjusted simultaneously from one of three points. Only one-quarter turn needed on socket wrench to tighten or loosen.



• *(left)* Note modern instrument panel with air controlled lever directly below.
• *(below)* Action view of Wilson Streamlined Titan Model Rotary Rig with hydromatic brake.



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Record Attendance Marks of Natural Gasoline

ON May 17, the Natural Gasoline Association of America closed its three-day annual meeting in Tulsa, Oklahoma, one of its most successful. Registration exceeded that of any meeting within recent years.

T. R. Goebel, Shell Oil Company, Inc., St. Louis, Missouri, was chairman of the morning session of the opening-day program, May 15.

George P. Bunn, Phillips Petroleum Company, president of the Association, delivered the opening address. He commended manufacturers of natural gasoline upon their continued and diligent research work despite the present uneconomic position of the product.

"New Test Methods and Specifications for Liquefied Petroleum Gases," by C. R. Williams, Continental Oil Company, was a report of the Technical Committee, of which the speaker is chairman. New tentative standards for liquefied gases were presented and activities of the committee reviewed.

Another committee report was that of James E. Allison, Hanlon-Buchanan, Inc., chairman of the Gas Contract Committee. His discussion concerned the committee's studies of the N.G.A.A.'s 1939 revised contract form for casinghead gas.

H. E. Felt, Warren Petroleum Corporation, presided at the afternoon meeting, which was opened by H. H. Anderson, vice-president, Shell Oil Company, Inc., who talked on conditions of the industry in Illinois, pointing out, among other things, its rapid climb from seventeenth among oil-producing states to third, a position it attained early this year. His talk was illustrated by slides and was one that had previously been sponsored by the St. Louis Chamber of Commerce.

James W. Vaiden, Skelly Oil Company, gave an unusually comprehensive picture of the development of, and the economics involved in, the liquefied petroleum gas business as related to the manufacture of natural gasoline.

"The Value of Standardization to the Pacific Coast Natural Gasoline Industry" was the title of the paper presented by W. W. Robinson, Jr., The Texas Company of California. Robinson is chairman of the Technical Committee of the California Natural Gasoline Association and he reviewed the work done by that group and its significence in California operations.

George P. Bunn (left), president of the Natural Gasoline Association of America, presenting to Dr. George Granger Brown of the University of Michigan, the Hanlon Award for meritorious service to the natural gasoline industry

A feature of the second day's session was the awarding of The Hanlon Award to Dr. George Granger Brown, professor of chemical engineering at the University of Michigan, for meritorious service to the natural gasoline industry during the last year. The award is sponsored by the Natural Gasoline Association of America, the donor being E. I. Hanlon, chairman of the board of the National Bank of Tulsa and of the Hanlon Companies. In addition to the public acknowledgement of meritorious service, the recipient of the award was also given a gold watch and chain and his name will be engraved on a bronze plaque that hangs permanently in the offices of the Association. The presentation was made by George P. Bunn, president of the Association.

At the same session, H. L. Oder, Cities Service Oil Company, chairman of the Gas Testing Committee, had for his subject "Revised Charcoal Method for Testing Gas." A modernized tentative version of this field method for determining the gasoline content of natural gas was presented.

R. C. Alden, Phillips Petroleum Company, presented a paper on "Neo-Hexane, the Fuel of Tomorrow", in which he discussed the combination by alkylation of light paraffin hydrocarbons such as ethane, propane, and butane with olefins to produce neo-hexane, which is an iso-paraffin, high octane number aviation fuel.

Because H. B. Bernard, consultant of Tulsa, Oklahoma, was ill with pneumonia, the paper prepared by him on "The Position of Natural Gasoline in Conservation" was presented by J. A. La Fortune, vice-president, Warren Petroleum Corporation.

Ray E. Miller, Hanlon-Buchanan, Inc., presided at the morning meeting.

At the afternoon session E. O. Bennett, Continental Oil Company, was chairman.

In his paper "Developments in Gas Recycling Plants", E. E. DeBack, Corpus Christi Corporation and Coastal Recycling Corporation, discussed the development of gas recycling plants, their economic aspects, and gave operating suggestions.

Dr. George Granger Brown's paper was entitled "The Measurement of Gas Flow Under High Pressure". In it he presented a method for calculating the

Nineteenth Annual Meeting Association of America

deviations from Boyle's Law of high-pressure gaseous mixtures based on the application of theoretical data to actual field measurements. The data presented in the paper are based on research work preformed by Dr. Brown.

A prepared discussion of Dr. Brown's paper was given by C. E. Webber, Humble Oil and Refining Company.

The final day's meeting, except for one paper, was an all-day session devoted to presentation of "Operating Kinks". The paper was on "Elimination of Hydrate Trouble" and was presented by E. G. Hammerschmidt, Texoma Natural Gas Company.

Hydrocarbon hydrates in which water is present in simple molecular proportions cause most freezing troubles in natural gas pressure systems, said the speaker.

At the "Operating Kinks" session original ideas were submitted by field, plant, and laboratory men. This is a prize contest, but aside from that fact it is always one of the best attended sessions of the meeting because of the many ideas presented. Awards are offered in four classes, depending upon the type of work in which the contestant is engaged. This year there were no entries in Class C.

The grand prize winner came from Class B, the award going to D. B. Young, J. E. Crosbie, Inc., Fittstown, Oklahoma, for his liquid level controller.

Other winners in Class B were:

Second prize—"Hydraulic Pump for Hydrostatic Testing," by Roy Magerkurth, Phillips Petroleum Company, Oklahoma City, Oklahoma.

Third prize—"Kink to Empty, Check and Refill Sealing Liquid Pots," by Richard W. Weeks, Phillips Petroleum Company, Phillips, Texas.

Fourth prize—"Dials for Indicating Orifice Size Within a Daniels Orifice Fitting," by Richard W. Weeks, Phillips Petroleum Company, Phillips, Texas.

Honorable mention—"Tank Pressuring with Flue Gas," by John L. Boyd and E. A. Thoes, Shell Oil Company, Inc., Orlando, Oklahoma.

Class A winners are:

First prize—"The Easy Packing Puller," by Hugh T. Greiner, Gulf Oil Corporation, Seminole, Oklahoma.

Second prize—"Automatic Shut Down Device," by J. R. Green, Skelly Oil Company, Carter Nine, Oklahoma.

Third prize—"Bearing Cone Puller," by W. A. Ryan, J. E. Crosbie, Inc., Fittstown, Oklahoma.

Fourth prize—"Ignition System," by W. H. Williams, Warren Petroleum Corporation, Graham, Oklahoma.

Honorable mention—"Cylinder Head Puller," by B. F. Gilstrap, J. E. Crosbie, Inc., Fittstown, Oklahoma.

Class D winners were:

First prize—"Gate Tester," by J. M. Hester, Skelly Oil Company, Shidler, Oklahoma.

Second prize—"Condenser Tube Tester," by Harvey Miller, Phillips Petroleum Company, Oklahoma City, Oklahoma.

Third prize—"Pump Arrangement to Take Gas Samples From Vacuum Lines," by H. E. Chambers, Skelly Oil Company, Lyman, Oklahoma.

Fourth prize—"Fitting Thread Leak Clamp," by Roy Magerkurth, Phillips Petroleum Company, Oklahoma City, Oklahoma.

Honorable mention—"Mercury Trap for a Manometer Tube," by Clyde E. Whitecotton, Skelly Oil Company, Fairfax, Oklahoma.

On "Operating Kinks" Day, Gene Middlebrook, Shell Oil Company, Inc., was chairman of the morning session, and H. H. Beeson, Sabine Valley Gasoline Company, chairman of the afternoon meeting.

At the annual election all officers of the Association were reëlected for the 1940-41 term. These are:

President: George P. Bunn, Phillips Petroleum Company, Bartlesville, Oklahoma.

Vice-Presidents: J. R. Jarvis, Lone Star Gasoline Company, Dallas, Texas; Ray E. Miller, Hanlon-Buchanan, Inc., Tulsa, Oklahoma; and J. W. Vaiden, Skelly Oil Company, Tulsa, Oklahoma. W. F. Lowe was again named secretary.

The N.G.A.A., in choosing its directors, selects the companies from which they will come, the company in turn naming the individual. New directors, to serve a two-year term, will be from the following companies:

Phillips Petroleum Company, Bartlesville, Oklahoma; Hanlon-Buchanan, Inc., Tulsa, Oklahoma; Skelly Oil Company, Tulsa; Standard Oil Company of California, San Francisco, California; Kansas Power and Light Company, Salina, Kansas; Indian Territory Illuminating Oil Company, Bartlesville; Coltexo Corparation, Monroe, Louisiana; United Gas Pipe Line Company, Shreveport, Louisiana; Warren Petroleum Corporation, Tulsa; Glacier Production Company, Cut Bank, Montana; Glen Rose Gasoline Company, Tulsa; Lisbon Gasoline Company, Shreveport; Carter Oil Company, Tulsa; and Sabine Valley Gasoline Company, Shreveport.

The following elected to a two-year term last year complete the board of directors:

Lone Star Gasoline Company, Dallas; Parade Gasoline Company, Shreveport; Continental Oil Company, Ponca City; Carbide and Carbon Chemicals Corporation, New York; Shell Oil Company, Inc., Tulsa; Union Oil Company of California, Los Angeles; Texas Pacfic Coal and Oil Company, Fort Worth; Oklahoma Gasoline Plants, Inc., Sapulpa, Oklahoma; Owens, Libbey, Owens, Gas Department, Charleston, West Virginia; Virginian Gasoline and Oil Company, Charleston, and Cities Service Oil Company, Bartlesville.

On the afternoon of May 15, the Natural Gasoline Supply Men's Association held its annual meeting in conjunction with the N.G.A.A. New officers and directors elected are:

President: W. W. Woobank, Woobank Pump and Machinery Company.

First vice-president: L. S. Allen, National Tank Company.

Second vice-president: George W. Probst, Clark Bros. Company.

Treasurer: D. A. Leach, Chicago Bridge and Iron Company.

New directors for a two-year term are: D. A. Leach; Charles D. Peterson, Fisher Governor Company; R. T. Roberts, Gould Pumps, Inc.; Egon Koehler, Moorlane Company; W. M. Gebo, Ingersoll-Rand Company; and V. C. Canter, Frick-Reid Supply Corporation.

Directors held over from 1939 include: A. J. Kerr, Pittsburgh Equitable Meter Company; W. W. Woobank, Woobank Pump and Machinery Company; L. S. Allen, National Tank Company; George W. Probst, Clark Bros. Co., and George P. Bunn, Phillips Petroleum Company.

W. F. Lowe was also reëlected secretary of this organization.

International Petroleum Exposition Has Colorful Opening

THE petroleum industry would rather serve a world at peace and make less money than pocket heavy profits at the cost of broken lives in time of war, President W. G. Skelly of the International Petroleum Exposition asserted at opening day ceremonies.

Rain poured on the sprawling exposition grounds, driving the opening ceremonies indoors and causing postponement of the big event of the program—the raising of the giant American flag between two oil derricks on each side of Drake Drive, main street of the exposition.

Governor Leon C. Phillips of Oklahoma, B. C. Heacock, president of the Caterpillar Tractor Company, Andrew F. Schoeppel, chairman of the state corporation commission of Kansas, and Mayor C. H. Veale of Tulsa shared the opening ceremonies microphone with Skelly.

Governor Phillips welcomed delegates to the show and praised the oil industry as one that "so far has been able to operate under its own steam, without any kind of outside help — even including federal subsidy."

"Oklahoma is proud of this exposition because we regard it pretty much as a state-wide project," he said. "We are proud, too, of Oklahoma's oil men —among the leaders in the industry— because we know that they use the most modern equipment and tools to safeguard the resources of our state.

"We are enabled here at this exposition to show as a matter of pride the materials that enable us to protect and produce the natural resources with which Oklahoma is so richly endowed. We want you to feel that you are doubly welcome to the state," Phillips said.

Schoeppel brought greetings to delegates and exposition officials from Governor Payne Ratner of Kansas. He said he was proud to be connected with an industry that had made such momentous strides during the past few years.

Eleven radio stations carried the program, which included music by the

Left to right: Mayor of Tulsa C. H. Veale, B. C. Heacock, president of Caterpillar Tractor Company; Governor Leon C. Phillips, and Wm. G. Skelly, president and host of the International Petroleum Exposition, at the opening ceremonies, Saturday, May 18

"Come to see us"...

International Petroleum Exposition - Tulsa, Okla., May 18-25
American Petroleum Institute Meeting - Fort Worth, May 27-31

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LOOK FOR THE BLUE NEON DERRICK

Governor Leon Phillips welcoming delegates from all parts of the world to the International Petroleum Exposition and Oklahoma. This is one of the few photographs showing Governor Phillips minus his big black cigar

American Legion Band of the Joe Carson post in Tulsa.

T. P. "Putty" Gilmer, Tulsa veteran master of ceremonies, handled introductions and generally ran the program through on schedule.

John A. Silsbee, Tulsa petroleum engineer, drew the tough assignment of reading off the list of foreign delegates who registered Saturday. His acquaintance with four languages besides his own enabled him to run through the list of tongue-twisters with a minimum of bobbles, to the amazement of spectators and officials alike.

President Skelly reminded listeners that much of the world today is involved in war "for political power and economic supremacy."

"Let us not forget that the product of our industry is the one vital essential to both military victory and industrial progress," he said. "We not only control — we actually produce nearly two-thirds of the world's supply of oil.

"And while the government is urging unprecedented expenditures and industrial preparedness for national defense the great oil industry of America is prepared to render a great patriotic service to its country. Without subsidy coersion or government financing, the petroleum industry is ready, equipped and willing to duplicate its successful and patriotic effort in the first world war."

Skelly said that through the use of the airplane, the tank and motorized warfare, recent events have proven the American oil industry to be far more valuable and indispensable than it was in 1917 and 1918.

He sketched the steady growth of the International Petroleum Exposition, pointing out that it is the largest exposition in the world devoted to a single industry. This year's show, he said, exceeds all previous events in its history, both in number of exhibitors, extent, variety, and value of exhibits, and in educational importance to the oil business.

"The petroleum industry and the allied industries represented in the exhibits displayed at this show exemplify the courage, confidence and resourcefulness, the ingenuity and free enterprise, of American business men.

"The oil man is a pioneering spirit, an empire builder, an explorer on the frontier of new fields of human endeavor seeking new scientific depths to plumb and new worlds to conquer. No industry has contributed so much to, or benefitted as greatly from, the new discoveries in science, engineering and invention."

B. C. Heacock, president of Caterpillar Tractor Company, one of the principal speakers at the opening ceremonies

B. C. Heacock, president of the Caterpillar Tractor Company, praised the initiative of the professional men — the engineers inventors and technicians—for continuing to apply themselves to big problems in spite of depressions and calamity howlers.

"Since 1929," he said, "all of us have howled lustily about the depression, and perhaps rightfully so. But the technical man—the engineer and the chemist and the research man—hasn't paid much heed—he's just gone ahead, plugging along, bending his energies toward the never-reaching goal, an ever higher standard of living for all of us.

"Too many of us are wont to believe—and perhaps it has become an habitual belief, that 1929 marked the all-time peak of prosperity.

"We can't seem to envision the day that will ever surpass that golden era. Yet look what the engineer, the scientist, has done in the interval. Look what he has done in the oil industry. Check it up and you will find that during the past ten years there hasn't been a single year but that some noteworthy achievement in the realm of science has materialized through the brains and effort of your industry's engineer-scientists."

Heacock said that short-sighted people have cried that "America has changed. Our frontiers are gone. Our opportunities have disappeared."

"Nothing of that kind has bothered our engineers," he continued. "They recognize no frontiers. For them there is always the vast unexplored worlds of endeavor and opportunity."

The Exposition, Heacock asserted, is "an eloquent pean of praise to their genius and their achievement."

He praised the oil industry for taking young people, fresh from colleges and universities, and training them for good jobs.

"It has been a most successful policy and a most beneficial one. In the

Mayor C. H. Veale of Tulsa, welcoming visitors to the International Petroleum Exposition during the opening ceremonies

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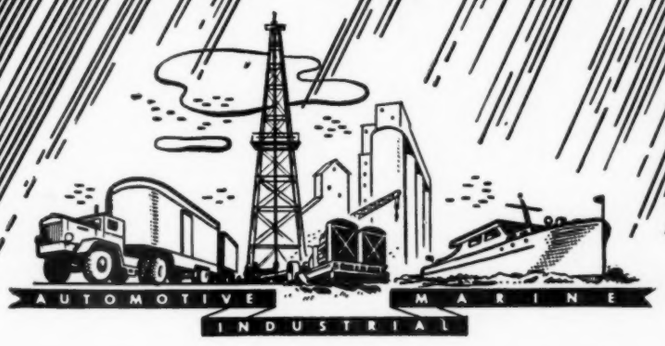

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oil fields and in the laboratories these young men are training themselves to be tomorrow's leaders of the industry."

Heacock had praise for Tulsa.

"There are a great many cities which have all the opportunities in the way of population, location and facilities that Tulsa has, but how many of them have, or are able to sponsor an exposition of this size, scope and completeness? So the answer must lie somewhere in, beyond and behind your progressive leaders. I am beginning to believe that you as the present generation of the progressive Southwest are the answer. Yours is a young city—a young state. The spirit of pioneering is still pretty much with you. You don't have to go back far to reach the pioneers who first built this city and formed this state. The results, some of which are seen here today, prove it."

Between 10 and 15 million dollars worth of exhibits greet those attending the International Petroleum Exposition holding its eleventh show in Tulsa, May 18 to 25, as compared to the $10,000 exhibit in improvised buildings near Tulsa's Convention hall at the first show in 1923.

The rapid growth of this huge show is a reflection of the growth of the 81-year-old petroleum industry, one that has seen its period of greatest growth in the twentieth century and is one of the largest industries of that period.

A handful of Tulsa business men were responsible for the first show, conceiving it as a local affair, with more merchants and business men on the first board of directors than there were oil men.

They have seen it grow far past their fondest hopes, with a $750,000 plant, including six major buildings and more than 30 private structures, covering 25 acres of ground. Its board of directors now consists of more than 100 leading oil men and equipment manufacturers from border to border and coast to coast.

The Exposition is a non-profit institution owned and controlled by the oil industry and drawing oil men from every continent.

This year 628 exhibitors fill all the available space, more than living up to the high expectations of the board of directors.

Other additions to the plant for 1940 not already mentioned include the enlargement of the office building to include a clubroom for exhibitors, the erection of the new International Delegates building and the construction of 10 new privately-owned exhibition buildings on the grounds.

Registering at the International building are two foreign delegates. On the left is A. H. J. van Goeh from Java, Dutch East Indies. On the right is Emilio Rodriguez from Havana, Cuba

P 615.1
P 621.

Laws of Fluid Flow In Rough Pipes

Experimental work extends the determination of friction factor, f, into the region of flow conditions of existing high-pressure transmission lines

PART 2

By J. NIKURADSE

Perhaps no single work, since Weymouth's, has contributed so much of practical value to the knowledge of flow conditions in pipe lines as this paper by Nikuradse. Appearing in *Forschungsheft*, publication of Verein Deutsch Ingenieurs (German Society of Engineers) in 1932, it has been unavailable to American engineers except in the German version. Publication, even seven years after its appearance in Germany, is justified as an answer to the many requests from engineers in this country who desire to avail themselves of the data contained herein.

Due acknowledgment is hereby given to the Panhandle Eastern Pipe Line Company, 90 Broad Street, New York, New York, for permission to publish the English translation of the paper.

Experimental Work (Continued)

WATER from the spare channel *vk* is pumped into the cistern *wk* by means of a centrifugal pump *kp* which is operated by an electric motor *em*. It is then returned to the spare channel *vk* through the experimental pipe *vr*. This arrangement was used for investigations at average and large Reynolds Numbers, but for measurements at small Reynolds Numbers an overflow was permitted. The water flowed out of the water piping through the feed pipe *zl* into the cistern *wk*. An ascending pipe *str* connected to the boiler conducted the surplus water over the collecting jar through the descending pipe *fr*. The outlet of the experimental tube was thus throttled as required. In order to obtain the highest Reynolds Numbers, the cistern *wk* is maintained at a definitely high pressure. The following measurements are made: 1. pressure head, 2. velocity distribution immediately on discharge from the experimental pipe, 3. quantity of flow, and 4. temperature of the water.

Three bent tubes with side drillings are used for measuring the pressure head. The velocity distribution was measured by a pitot tube having an inside diameter of 0.2 mm., located in the velocity measuring apparatus, *gm*, and movable in a horizontal and vertical direction. The quantity of flow in a measuring vat *mb* to a Reynolds Number, Re = 300,000 was determined from the height of the water and from the time. The larger quantities were estimated by integration of the velocity distribution. The temperature was measured in the velocity-discharge measuring apparatus *gm*. Brass tubes under tensile stress and with circular cross-section were used as experimental material, whose dimensions are listed in Table 1. Tube diameters were established from the weight of water that could be forced into the tube when closed at the ends and from the length of the tube.

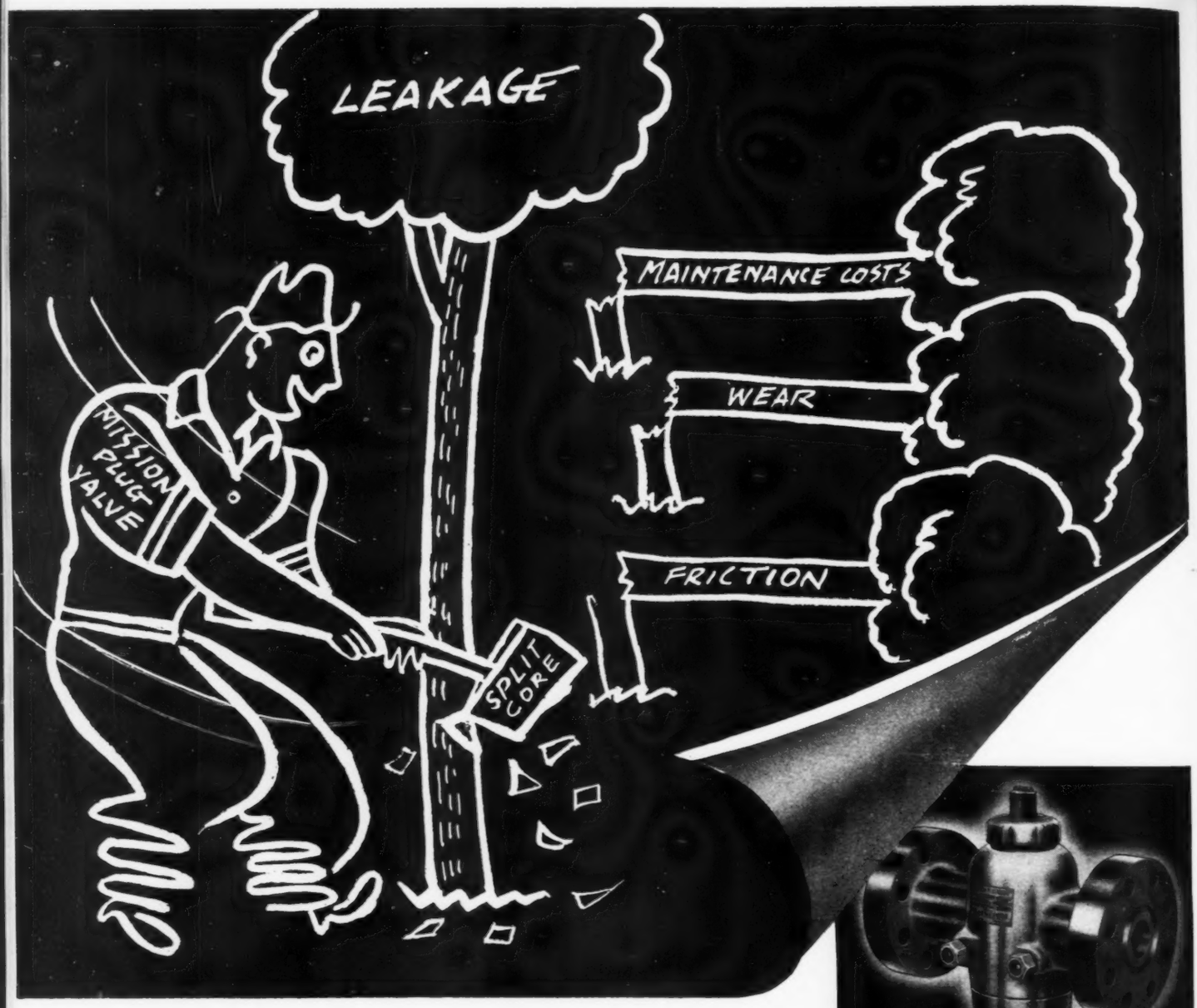
2. Preparation and determination of roughness. In order to produce a mechanically-similar flow in two pipes, the following conditions must be fulfilled in accordance with the laws of similarity: both pipes must have a geometrically similar shape and a similar wall characteristic. The first condition was fulfilled in that pipes with circular cross-section were selected. The second condition was fulfilled in that the ratio of pipe radius r to elevation of roughness k remained constant. It was mainly necessary that the bodies causing roughness should be similar to one another. Sand was selected as the roughening body in accordance with the suggestions of Prof. D. Thoma.

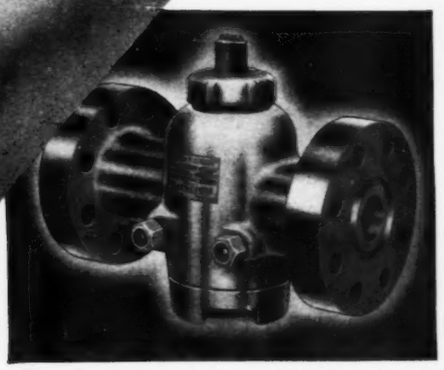
In order to produce equal roughness in the entire pipe, the presence of grains of equal size is necessary. For that reason ordinary building sand was sifted: for example, to obtain the mean grain size of 0.8 mm. diameter it was sifted with strainers of about 0.82 and 0.78 mm. mesh. In order to determine the actual mean size of the particle the average diameter of several hundred grains was ascertained by a Zeiss thickness gauge. Several hundred sand particles were strewn on a flat plate. The individual grains were then checked by displacement of the plate with the Zeiss thickness gauge, which has an accuracy of measurement of 0.001 mm. The arithmetical mean obtained in the given example was about 0.8 mm.

The pipes were rendered rough by sand prepared in this manner and in accordance with a method determined by preliminary tests. After placing the pipe in a vertical position and closing the lower end, the pipe was filled with a very thin solution of Japan lacquer and then emptied. After the elapse of half an hour, which was sufficient to allow the lacquer adhering to the wall of the pipe to dry "tackily," the pipe was then completely filled with sand of a definite graduation. The sand was then drawn-off beneath. The subsequent drying, as was shown by the preliminary experiments, is very important for durability. In each case a period of drying from two to three weeks is necessary depending on the atmospheric humidity. In order to obtain a uniform drying, an incandescent lamp is placed under the lower end of the pipe and a uniform circulation is thus produced. After this drying, the pipe is filled once more with lacquer and then re-emptied, for the purpose of obtaining better adhesion of the grains. This is followed by another period of drying lasting from three to four weeks as has been described above. In order to avoid a possible clogging of the pipes at the ends, a length of about 10 cm. is cut from each end. After this process the pipes were capable of being measured.

From the aforementioned condition it follows that for pipes of various diameters, different sizes of grain must be used, so that the ratio r/k, the measure for similar wall character, remains constant. The geometric similarity of the wall character demands that the shape of the individual grains be similar and thereby the hydrodynamically-effective elevation of roughness remains constant. Photomicrographs of the sand show that interstices exist between the

(Continued on page 78)





Test Pressures: 4,000 to 10,000 lbs. Tested on drilling rigs, flow lines and Christmas trees for 24 months without a failure.

Mission's New Plug Valve

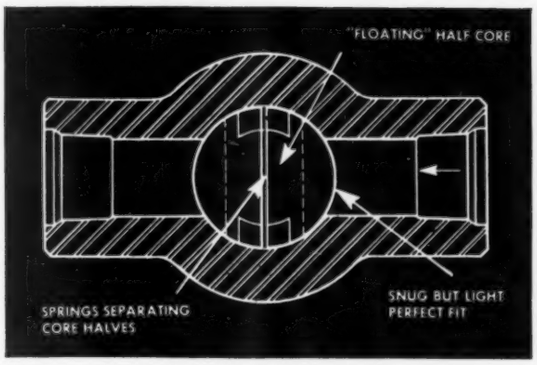
has a super-surfaced, leak-proof split core. This cuts down friction, wear and maintenance costs — also assures easy opening.

Three new features of the Mission Plug Valve will completely satisfy you that it will operate easily and give long, continuous use without leakage—even under severe conditions.

The Super-Surfaced Split Core. Splitting the core prevents any possibility of binding, and permits grinding each core half to a perfect fit. Under line pressure the upstream half "floats" — all the pressure and the only friction are on the downstream side of the valve. This is another reason why the Mission valve opens easily. In addition, friction and wear are further reduced, as the core is file-hard, corrosive-proof, and super-surfaced. This "super-surfacing" is an expensive treatment which gives the core a smooth, glazed surface.

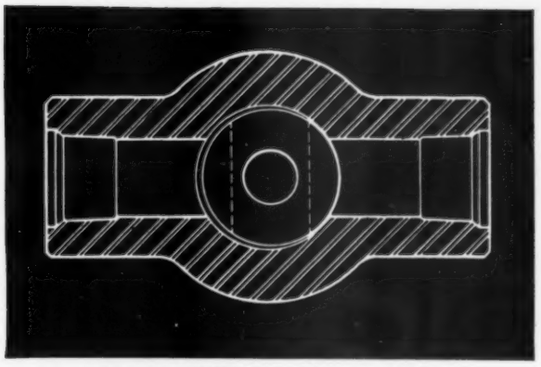
The Cylindrical Core Prevents Wedging. This enables the Mission valve to operate more easily than the old-style valve with a tapered plug. Wear is reduced and leakage is checked because a perfect seal can be constantly maintained as the straight plug always fits its seat perfectly.

Automatic Lubrication Assures a Perfect Seal. Mission, exclusively, uses line pressure to force the sealing lubricant from storage reservoirs to grease grooves which completely encircle each port opening. This constant pressure assures a perfect seal as long as a supply of grease is maintained in the reservoirs. This system adds indefinitely to the life of the valve and makes operation easier as well.



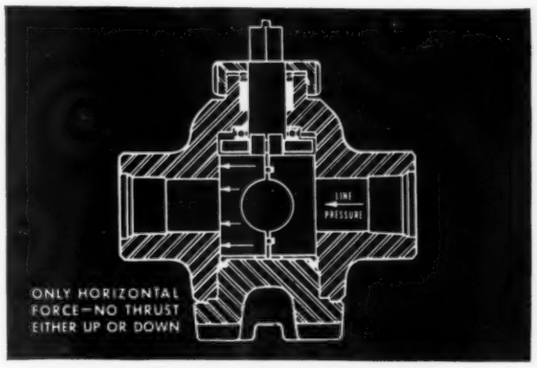
MISSION SPLIT CORE

Perfect contact with body allows instant seal under pressure. This protects surfaces from sand and grit, reduces cutting and wear, and reduces maintenance costs.



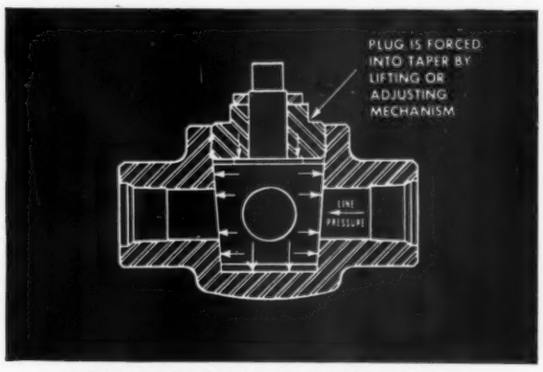
CONVENTIONAL SOLID PLUG

Unless wedged, a solid plug cannot fit its seat perfectly. As the plug wears, it cannot fit. This permits accumulation of sand and grit, accelerating wear, and greatly increases difficulty of operation.



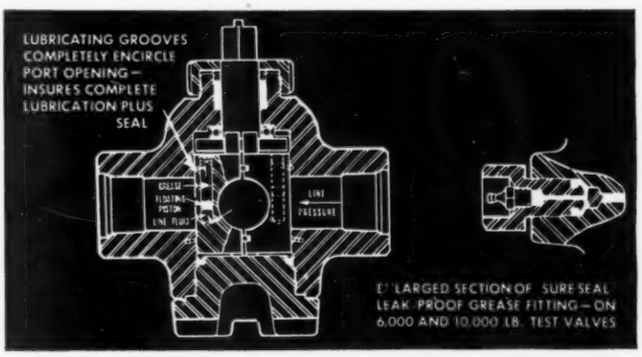
MISSION STRAIGHT CORE

Our cylindrical plug seats perfectly with minimum side wall clearance because of its design. A constant seal and complete lubrication are easily maintained. This increases valve life and assures easy operation.



CONVENTIONAL TAPERED PLUG

A tapered plug also has vertical motion. It can seat perfectly only when wedged. Greater side wall clearance in operation makes a perfect seal difficult and allows opportunity for sand to accumulate under the seat. This increases friction and wear.


LUBRICATING GROOVES COMPLETELY ENCIRCLE PORT OPENING—INSURES COMPLETE LUBRICATION PLUS SEAL
GREASE FLOATING PISTON LINE FLUID
LINE PRESSURE
ENLARGED SECTION OF SURE SEAL LEAK-PROOF GREASE FITTING—ON 6,000 AND 10,000 LB. TEST VALVES

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Line pressure against piston in each lubricating storage reservoir automatically forces and holds sufficient lubricant in place in the grease grooves around each port to both lubricate and form a perfect seal at all times regardless of pressure.

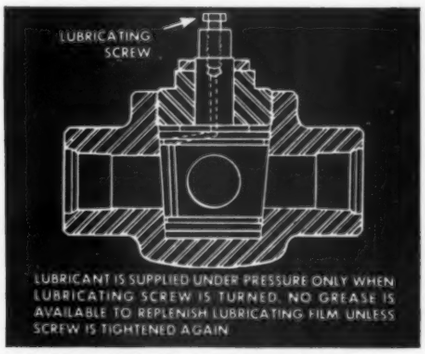
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Table I

Dimensions of Experimental Pipes

d = inside diameter of the pipe; l_e = intake length; l_1 = measuring section I; l_2 = measuring section II; l_a = length of outlet; x = total length; x/d = relative total lengths.

d mm.	l_e mm.	l_1 mm.	l_2 mm.	l_a mm.	x mm.	x/d
25	750	500	500	50	1800	72
50	1495	1000	1000	75	3570	71.4
100	4000	1500	1000	550	7050	70.5

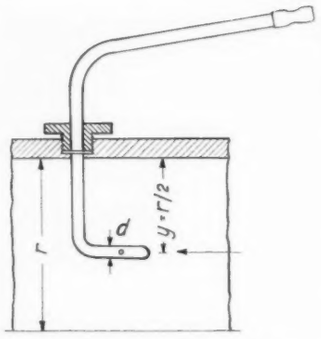

Fig. 4. Bent-tube assembly

(Continued from page 75)

individual particles. Consequently, the hydrodynamically-effective elevation of roughness k is equal to the thickness of the grain. In order to determine whether the previously-measured thickness of the grains actually existed, a flat plate was coated with a thin solution of Japan lacquer (degree of diluteness was established by preliminary tests) and roughened in accordance with the aforementioned method. In this manner the differences in height between the sand grains and the areas of tube wall free from grains were now determined. The result showed that with a definite degree of diluteness of Japan lacquer the mean value corresponded to the size of grain measured previously.

3. Measuring the pressure head. In flow along smooth pipes the fall in pressure may be measured along the tube through holes drilled in the wall. Determination of pressure drop in rough pipes by this method produces considerable error.

These errors arise from the fact that the whirls that develop as the fluid circulates over the elements of roughness produce a suction or pressure effect, each according to the position of the hole through the tube wall. The measurement of pressure drop in rough pipes is executed, therefore, by means of a bent pipe. The tube, as shown in Fig. 4, is bent at right angles and fitted into the experimental flow pipe so that the bent end section lies parallel to the direction of flow. This section has only side drillings. The external diameter *d* of the bent pipe is 2 mm. The bent tube is designed in accordance with the plan for the Prandtl measuring pipe[11]. The inner section is spaced from the tube wall by a distance, *y*, equal to half the radius of the experimental pipe. The connecting arm is bent to about 60° in the plane of the right-angle bend in order to have constant control over the position of the inner end of the pipe. The bent pipe is fixed into the experimental tube by means of a stuffing-box.

The accuracy of the pressure reading through a bent pipe is dependent upon the location of the pipe with relation to the direction of flow. Consequently, a correct indication can be obtained only if the axis of the bent pipe does not deviate more than 7.5° from the direction of flow. By inserting the bent pipe into the experimental tube the fall in pressure will be increased by the resistance of the bent pipe. The resistance of the two bent pipes, which are used for measuring, will, therefore, have to be deducted from the measured fall in pressure, $p_1 - p_2$.

For this reason, the resistance of the bent tube has to be known. The resistance was arrived at by first determining the pressure head *h* depending on the quantity of flow at a constant temperature by drilling the walls of a smooth pipe. Hence, the fall in pressure $h + a$, depending on the quantity of flow at the same temperature, was measured by means of a bent pipe. The difference, a, of the indication with a corresponding quantity of flow gives the resistance of the bent tubes. In this connection it must be pointed out that deviation of the bent tube axis will not only result in an incorrect indication of the pressure but an increase in the resistance of the bent tube will also occur.

11. *s. H. Kumbruch:* Mossung strömender Luft mittels Staugeräten. Forsch.-Arb. Ing.-Wes. Heft 240 (1921).
A. Hoffman: Der Berlust in 90° -Rohrkrummern mit gleichbleibendem Kreisquerschnitt. Mitt. hydraul. Inst. T. H. Munchen, herausgeg. v. D. Thoma, Heft 3 (1929) S. 55.

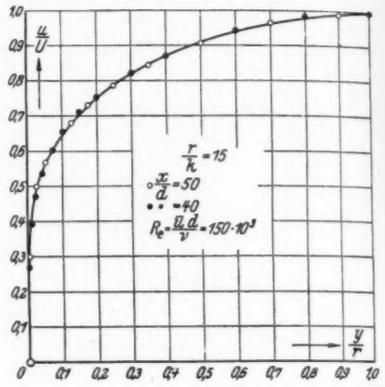

Fig. 5. Data on distribution of velocity

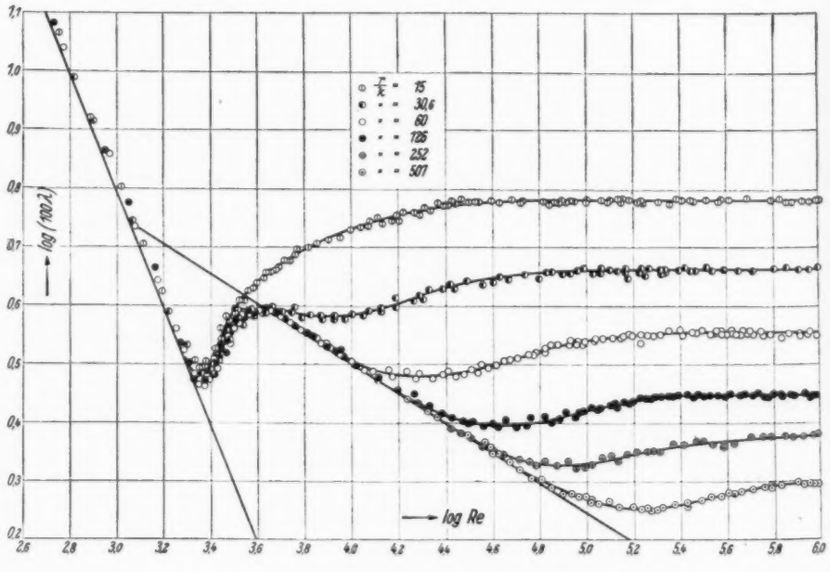

Fig. 6. Plot of experimental data in Tables 2 to 7

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TABLE 2

ū cm/s	ν cm²/s	$\frac{dp}{dx}$ dyn/cm³	lg *Re*	lg (100 λ)	$\frac{1}{\sqrt{\lambda}} - 2\lg r/k$	$\lg \frac{v_* k}{\nu}$	$\frac{2{,}83}{\sqrt{\lambda}} - C$	$\frac{\bar{u}}{U}$
			$r/k = 507$					
		$k = 0{,}01$ cm	$d = 9{,}94$ cm		$\lg r/k = 2{,}705$			
15,45	0,0118	0,000351	4,114	0,456	0,51	0,000	4,95	0,815
20,2	0,0118	0,000574	4,230	0,438	0,64	0,000	5,35	0,819
25,0	0,0118	0,000840	4,322	0,417	0,79	0,083	5,75	0,824
27,3	0,0118	0,000975	4,362	0,407	0,86	0,117	5,95	0,825
27,3	0,0118	0,000966	4,362	0,403	0,88	0,114	6,02	0,824
34,4	0,0118	0,001525	4,462	0,381	1,05	0,212	6,48	0,825
36,8	0,0118	0,00167	4,491	0,380	1,06	0,236	6,55	0,830
40,4	0,0118	0,00195	4,532	0,366	1,16	0,267	6,80	0,829
44,0	0,0118	0,00230	4,568	0,365	1,17	0,310	6,87	0,832
46,4	0,0118	0,00251	4,591	0,356	1,24	0,322	7,05	0,832
50,0	0,0118	0,00285	4,623	0,347	1,31	0,348	7,25	0,834
55,9	0,0118	0,00347	4,672	0,333	1,41	0,391	7,50	0,836
58,5	0,0118	0,00372	4,690	0,324	1,48	0,407	7,72	0,835
61,8	0,0118	0,00410	4,716	0,320	1,52	0,428	7,85	0,838
69,0	0,0118	0,00496	4,763	0,307	1,62	0,470	8,05	0,839
76,0	0,0118	0,00597	4,806	0,303	1,65	0,508	8,08	0,842
84,4	0,0118	0,00718	4,851	0,292	1,74	0,549	8,45	0,841
94,0	0,0118	0,00878	4,898	0,286	1,79	0,593	8,58	0,844
103,5	0,0118	0,01087	4,940	0,278	1,86	0,638	8,78	0,843
106,0	0,0112	0,01085	4,973	0,274	1,89	0,661	8,85	0,845
114,0	0,0112	0,01255	5,009	0,274	1,90	0,694	8,89	0,848
119,8	0,0112	0,01378	5,025	0,272	1,92	0,713	8,95	0,845
126	0,0112	0,01515	5,049	0,270	1,93	0,733	8,97	0,847
147	0,0116	0,0202	5,100	0,262	2,00	0,781	9,17	0,846
162	0,0116	0,0245	5,143	0,260	2,02	0,829	9,25	0,847
184	0,0116	0,0314	5,199	0,255	2,05	0,878	9,29	0,849
201	0,0116	0,0372	5,236	0,253	2,07	0,919	9,36	0,847
217	0,0116	0,0435	5,270	0,255	2,06	0,944	9,35	0,849
223	0,0116	0,0458	5,281	0,253	2,07	0,959	9,36	0,849
234	0,0116	0,0501	5,303	0,250	2,10	0,971	9,45	0,846
248	0,0116	0,0565	5,326	0,252	2,08	1,004	9,42	0,851
287	0,0120	0,0760	5,377	0,255	2,06	1,053	9,35	0,847
325	0,0120	0,0975	5,430	0,253	2,07	1,107	9,36	0,849
375	0,0120	0,1310	5,493	0,258	2,03	1,172	9,25	0,849
412	0,0120	0,1585	5,534	0,260	2,01	1,214	9,19	0,846
445	0,0118	0,1850	5,574	0,262	2,00	1,255	9,15	0,848
481	0,0118	0,2320	5,608	0,290	1,95	1,303	9,05	0,845
516	0,0120	0,2560	5,630	0,272	1,96	1,317	8,95	0,848
551	0,0118	0,2920	5,668	0,272	1,92	1,352	8,95	0,846
607	0,0118	0,3540	5,709	0,272	1,91	1,394	8,93	0,848
602	0,0105	0,3520	5,756	0,278	1,87	1,446	8,83	0,845
655	0,0105	0,4190	5,792	0,279	1,85	1,483	8,75	0,846
720	0,0105	0,5100	5,833	0,283	1,82	1,525	8,67	0,844
798	0,0091	0,6340	5,940	0,286	1,80	1,633	8,63	0,846
845	0,0091	0,7100	5,965	0,288	1,78	1,659	8,55	0,843
835	0,0086	0,5400	5,929	0,289	1,77	1,623	8,51	0,844
779	0,0086	0,6050	5,954	0,288	1,78	1,648	8,55	0,845
840	0,0086	0,7000	5,987	0,286	1,79	1,680	8,57	0,845

By dividing the fall in pressure, $p_1 - p_2$, thus corrected by the measuring section l (distance between the drilled holes in the two bent tubes), we obtain the pressure gradient:

$$\frac{dp}{dx} = \frac{p_1 - p_2}{l}$$

4. Preliminary tests. The problem of whether the artificially-created hydrodynamically-effective elevation of roughness remained constant was solved by preliminary experiments. The fall in pressure was measured every hour at a certain Reynolds Number when the average velocity ū was about 20 m. per sec. In this way it was established that within a few days the pressure gradient increased considerably. An accumulation of lacquer in the spare channel, vk, of the apparatus indicated that the lacquer was being washed-out. Another difficulty arose from the fact that the sand was partly removed in the process. Increase in the pressure gradient is to be attributed to the increase of roughness elevations due to the washing-out of the lacquer. Consequently before the experiments could be continued, a method had to be devised to make the sand adhere, always endeavoring to maintain the roughness elevation k constant and a uniform compactness of the grains on the pipe surface during the experiment.

A very thin lacquer prevented an agglutination of the sand grains, as the lacquer adhered immediately to the wall and coated the grains only to such an extent as they entered the lower layer of lacquer. In this manner, the original shape and size of the grains were maintained. This condition depended on the degree of thinness of the lacquer which was diluted by adding turpentine until the original size of the grain was maintained. Experiments with pipes that had not been coated with lacquer showed that the sand was removed by rinsing. It is for this reason that the lacquer coating was introduced. In cases where both lacquer coatings were given a brief drying period, the lacquer was similarly washed out. When the first drying period was short and the second one long, the entire lacquer layer was washed out. When the first layer of lacquer was given a long period of drying and the second one only a short period, then even sand came out. Only after both coatings of lacquer were each given a three to four weeks drying period, was the roughness maintained.

In order to test the correctness of the indication of the bent pipe, it was connected through a manometer to a wall drilling in the same cross-section of a smooth pipe. If both connections indicated similar pressures in the smooth pipe, the manometer would remain zero. The bent tubes tested in this manner were used for the main measurements.

Finally we determined the initial relative length, x/d. The velocity distributions were measured at the greatest relative roughness k/r = 1/15. For this purpose the velocities for the different wall distances y at the Reynolds Numbers, Re = 20,000, 70,000, and 150,000 were determined at different distances from the intake x/d, which were obtained by cutting off the experimental pipe. The experiments have shown that the change in the initial length with the Reynolds Number is not essential. The initial length is somewhat shorter than with smooth pipes, x/d = 40, Fig. 5. The initial length x/d = 50 was maintained, however, as in the case of smooth pipes.

Nomenclature For Tables 2 to 7

ū = mean velocity; γ = kinematic viscosity; $\frac{dp}{dx}$ = pressure gradient; $Re = \frac{\bar{u}d}{\gamma}$ Reynolds Number; $d = 2r$ = pipe diameter; $\bar{q}$ = dynamic pressure of the mean velocity; $\lambda = \frac{dp}{dx}\frac{d}{\bar{q}}$ = coefficient of resistance; k = mean roughness elevation; $v^* = \sqrt{\frac{\tau_0}{\rho}}$ = shearing stress velocity; τ_0 = shearing stress at the wall; ρ = density; U = maximum velocity.

$$C = 5.75 \log r/k - \beta$$

In these tables, the comma is equivalent to a decimal point, i.e., 0,00496 is 0.00496. The symbol, log, for logarithm appears as lg.

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TABLE 3

$\bar{u}$ cm/s	ν cm²/s	$\frac{dp}{dx}$ dyn/cm³	lg *Re*	lg (100 λ)	$\frac{1}{\sqrt{\lambda}} - 2\lg r/k$	$\lg \frac{v_* k}{\nu}$	$\frac{2{,}83}{\sqrt{\lambda}} - C$	$\frac{\bar{u}}{U}$
			$r/k = 252$					
		$k = 0{,}01$ cm	$d = 4{,}94$ cm		lg $r/k = 2{,}401$			
43,4	0,0132	0,0055	4,210	0,4506	1,15	0,290	6,77	0,816
51,0	0,0132	0,00728	4,279	0,4349	1,26	0,352	7,10	0,820
78,2	0,0132	0,01524	4,465	0,3808	1,65	0,513	8,21	0,830
86,0	0,0132	0,01775	4,507	0,3636	1,77	0,545	8,55	0,831
94,8	0,0132	0,0213	4,549	0,3579	1,82	0,584	8,68	0,830
104,0	0,0130	0,0255	4,597	0,3562	1,84	0,630	8,75	0,832
116	0,0130	0,0308	4,644	0,3434	1,94	0,672	9,01	0,836
158	0,0130	0,0549	4,778	0,3257	2,08	0,798	9,42	0,838
174	0,0130	0,0668	4,820	0,3282	2,06	0,840	9,36	0,840
214	0,0128	0,1000	4,916	0,3222	2,11	0,934	9,54	0,842
252	0,0128	0,1375	4,987	0,3197	2,12	1,003	9,55	0,841
296	0,0128	0,1900	5,057	0,3210	2,11	1,073	9,53	0,839
322	0,0126	0,2265	5,100	0,3228	2,10	1,118	9,50	0,837
382	0,0126	0,3160	5,173	0,3197	2,12	1,190	9,55	0,840
407	0,0124	0,365	5,210	0,3276	2,06	1,229	9,38	0,841
468	0,0120	0,490	5,283	0,3322	2,03	1,307	9,25	0,836
555	0,0118	0,702	5,366	0,3416	1,94	1,391	9,03	0,833
735	0,0116	1,257	5,494	0,3504	1,89	1,526	8,85	0,833
664	0,0086	1,037	5,580	0,3562	1,85	1,615	8,75	0,832
734	0,0086	1,280	5,623	0,3602	1,80	1,660	8,65	0,832
879	0,0086	1,850	5,702	0,3636	1,78	1,740	8,57	0,832
121	0,0117	0,0329	4,708	0,3371	1,99	0,732	9,15	0,836
486	0,0119	0,530	5,305	0,3328	2,03	1,328	9,25	0,836
854	0,0120	1,724	5,544	0,3562	1,85	1,580	8,75	0,832
1104	0,0089	2,925	5,787	0,3661	1,76	1,842	8,53	0,834
		$k = 0{,}02$ cm	$d = 9{,}94$ cm		lg $r/k = 2{,}401$			
72,3	0,0128	0,0058	4,748	0,3335	2,02	0,769	9,25	0,836
95,5	0,0128	0,00986	4,869	0,3228	2,10	0,884	9,46	0,840
116,0	0,0128	0,0144	4,954	0,3210	2,12	0,966	9,53	0,839
175,5	0,0128	0,0331	5,134	0,3210	2,12	1,146	9,53	0,840
232	0,0128	0,0589	5,255	0,3294	2,05	1,272	9,30	0,838
309	0,0118	0,1080	5,415	0,3434	1,94	1,458	9,02	0,830
452	0,0118	0,2375	5,580	0,3551	1,84	1,692	8,75	0,806
666	0,0118	0,522	5,748	0,3608	1,80	1,782	8,64	0,832
833	0,0118	0,828	5,845	0,3666	1,76	1,881	8,50	0,831
697	0,0091	0,583	5,881	0,3688	1,75	1,919	8,49	0,831
770	0,0091	0,719	5,924	0,3727	1,71	1,964	8,37	0,831
850	0,0091	0,872	5,967	0,3705	1,72	2,004	8,42	0,830
880	0,0089	0,816	5,991	0,3716	1,72	2,000	8,40	0,841

Development of the Experimental Data

1. Law of resistance. The coefficient of resistance of the flow in tubes is determined in a definite manner by the formula:

$$\lambda = \frac{dp}{dx}\,\frac{d}{\bar{q}} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where $\frac{dp}{dx}$ denotes the decrease in pressure per unit of length; d, the diameter $\bar{q} = \rho\frac{\bar{u}^2}{2}$; the dynamic pressure of the mean flow velocity $\bar{u}$; and ρ, the density. By an extended series of experiments within the range of the Reynolds Numbers, which extends from Re = 600 to Re = 10^6, the dependence of the coefficient of resistance on the Reynolds Number was investigated for tubes of varied roughnesses and six different relative roughnesses were employed. The relative roughness, k/r, is defined by the ratio of the mean elevation k to the tube radius r. When calculating the experimental results, however, it is evidently appropriate to do so by means of the reciprocal value r/k instead of by the relative roughness k/r.

In Fig. 6 the coefficient of resistance depending on the Reynolds Number for the reciprocal values r/k of the six different relative roughnesses and for the smooth pipe is plotted logarithmically on the graph, the lowest curve corresponding to the smooth pipe. (Editor's note: For the benefit of those who may wish to treat Nikuradse's experimental data mathematically, the original data obtained are presented in Tables 2 to 7.)

If we consider the curve for a certain relative roughness, we must distinguish three different ranges. The roughness for the small Reynolds Numbers in the first range has no effect on the resistance. In this case the curve $\lambda = f$ (Re) for each value r/k coincides with that of the smooth pipe. This range embraces the entire laminary field and part of the turbulent one, which is so much the larger, the smaller the relative roughness. Within the laminary field the coefficient of resistance holds good for the law:

$$\lambda = 64/\mathrm{Re} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2),$$

which is represented in Fig. 6 by a straight line with the inclination 1:1. In the first part of the turbulent region the Blasius law of resistance[12]

$$\lambda = 0.316/\mathrm{Re}^{1/4} \quad . \quad . \quad . \quad . \quad . \quad (3),$$

holds good for the smooth tube to about the Reynolds Number, Re = 10^5, which is illustrated in Fig. 6 by a straight line with the inclination 1:4. The critical Reynolds Number for all relative roughnesses lies at about the same point as for the smooth pipe, that is, between 2160 and 2500.

In the second range, which might be called the transitionary region, the effect of roughness is noticeable to a very great extent in that here the coefficient of resistance increases with the increase of the Reynolds Number. This transitionary region is characterized especially by the fact that the coefficient of resistance depends as much on the Reynolds Number as on the relative roughness.

Finally, in the third range, the coefficient of resistance is independent of the Reynolds Number; here the curve $\lambda = f$ (Re) runs parallel to the axis of abscissas. This is the region of the quadratic law of resistance.

The three given ranges of the curves $\lambda = f$ (Re) may be interpreted physically as follows:

In the first range the thickness of the laminary layer, which decreases with increase in the Reynolds Number, is still greater than the mean roughness elevation ($\delta > k$) and, therefore, no additional loss of energy is caused by the roughness as compared with the smooth pipe.

In the second range the thickness of the laminary layer is of the same order of magnitude as the mean roughness elevation ($\delta \approx k$). Some elevations project from the laminary layer. On these elevations whirls takes place that bring about an additional loss of energy. Owing to decrease in thickness of the laminary layer with increasing Reynolds Number more and more roughness elevations project from the laminary layer. The additional loss of energy increases with increase in the Reynolds Number, hence the rise of the curves $\lambda = f$ (Re) in this range.

Finally, in the third range the thickness of the laminary layer was reduced to such an extent that all roughness elevations project from it. The loss of energy, caused by the formation of whirls, has now reached a constant value so that with increase in the Reynolds Number, an increase in resistance no longer occurs.

EDITOR'S NOTE: This article will be continued in an early issue.

12. *H. Blasius:* Das Ahnlichkeitsgesetz bei Reibungsvorgängen in Flussigkeiten. Forsch.-Arb. Ing.-Wes. Heft 131, Berlin 1913.

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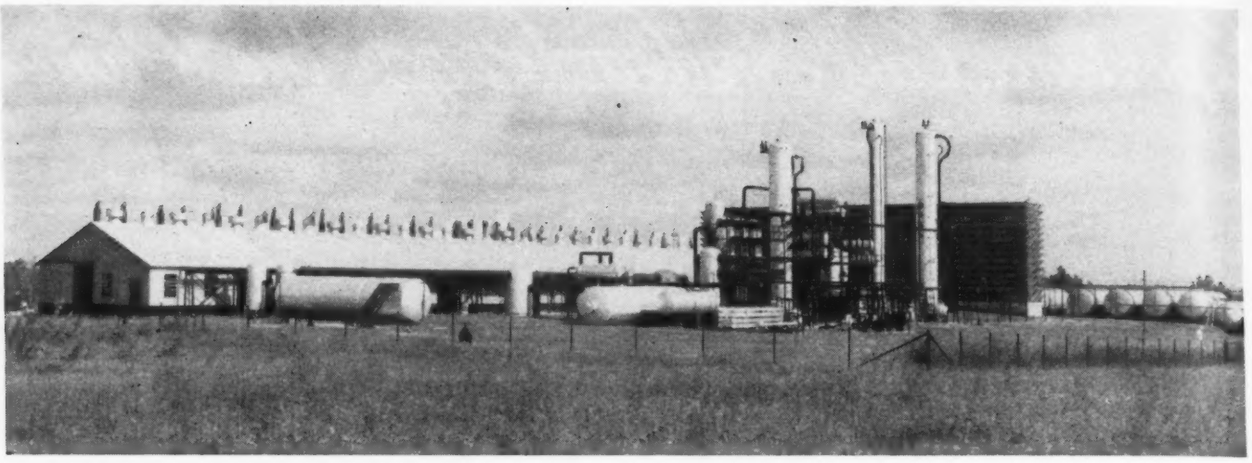


General view of Sabine Valley Gasoline Company plant

Operating Data on Gas-Engine-Driven Compressors in East Texas Gasoline Plant

Erratic loads necessitate clearance pockets or unloaders—Excessive heat of high B.t.u. gas is reduced by maintaining lower pressure on fuel to engines—Lubricants are selected to meet the specific needs of the equipment

By H. H. BEESON

Vice-President and Chief Engineer, Sabine Valley Gasoline Company, Inc.

FIVE years' operation has given Sabine Valley Gasoline Company, Inc., useful data on compressor and gas-engine operation at its East Texas plant four miles north of Kilgore, Texas. This plant began operating in April, 1935, with 11 units drawing casinghead gas into the plant under vacuum through 40 miles of pipe-line system and compressing it to the pressure required in the gasoline extraction process. The twelfth unit was added in the spring of 1936, and two units for compressing propane refrigerant were placed in service in July, 1937. All units are 230-hp., twin-cylinder, 2-cycle, horizontal, single acting Cooper-Bessemer gas engines direct-connected to compressor cylinders.

The specifications for the machines are shown in Table 1.

The capacity of the casinghead gas compressor is based on a suction pressure of 10 in. Hg. vacuum and a discharge pressure of 285 lb. gauge with a 3-lb. pressure drop between the low-stage discharge and the high-stage suction. The capacity of the propane compressor is based on 50-lb. gauge suction pressure and 190-lb. discharge.

In the usual East Texas casinghead gasoline plant, gas is processed from as many as 1500 to 2500 wells, the majority of which require less than an hour to flow their allowed daily production. This presents a serious problem in scheduling the gas flow evenly over a 24-hr. period to obtain a uniform gas load and a uniform suction pressure. Due to the possibility of the suction pressure rising above that for which the compressors were designed, additional clearance was designed into the low-stage cylinders. By adding clearance, the volumetric efficiency is decreased and thus less power is required as less gas will be compressed per stroke. With normal clearance, the cylinders were designed for a suction pressure of 10 in. Hg. vacuum, which would give the engines their rated load. Should the suction pressure increase, the engines become overloaded due to the increased volume handled. By inserting a ring between the cylinder and the cylinder head, additional clearance was obtained, allowing a higher suction pressure without overloading. It is anticipated that this ring will be removed when the suction pressure can be maintained more uniformly at 10 in., thus obtaining a slight increase in capacity.

H. H. BEESON

received a bachelor of science degree at Iowa State College in 1932—Worked with the Iowa Engineering Experiment Station on utilization of butane until 1934—Has been in the natural gasoline industry since that time—Is chief engineer and vice-president of Sabine Valley Gasoline Company, Inc.

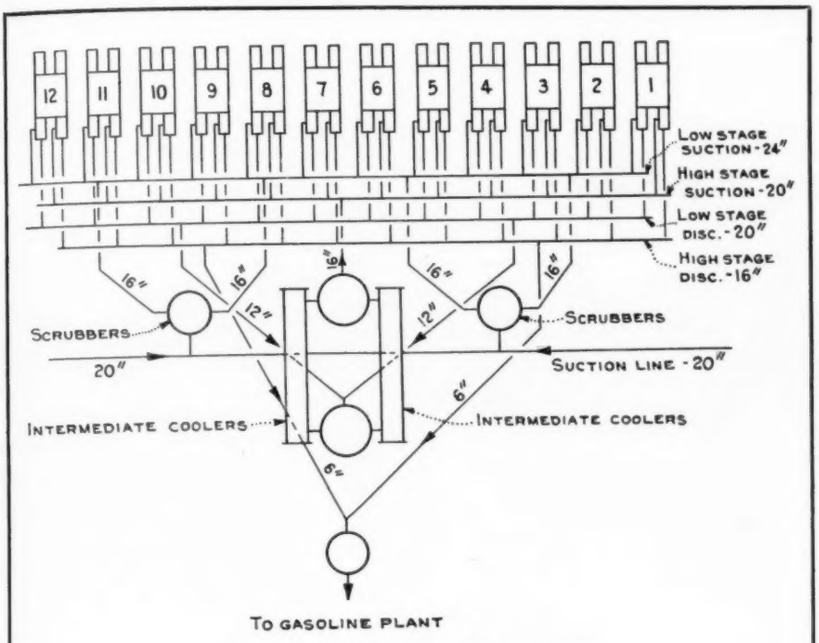


Fig. 1. Header and piping layout

In other installations adjustable clearance, or clearance pockets, may be installed that can be opened when the suction pressure increases and then closed again when the pressure decreases. By these devices, the efficiency may be kept at a maximum and more gas can be compressed. A disadvantage in this type of extra clearance is that it is difficult for the operators to adjust the clearance on each of a large number of machines if the gas load changes rapidly. Instead of using additional clearance in the cylinder, an increased gas load on a machine may be avoided by pinching the suction valve, but it is not easy to keep these valves adjusted so the machine will handle its maximum volume during such peak loads.

A factor that has contributed to successful operation is the header layout, which is designed for a minimum pressure drop. A sketch of this layout is shown in Fig. 1. It is important to have adequate header piping so that the suction and discharge pressures on all cylinders will be the same and cause no difference in the load on each engine. A smaller amount of power is required in multistage compression when a minimum pressure drop between stages is obtained by proper header design and proper design of the intermediate coolers and scrubbers. The intermediate pressure drop at the Sabine plant is less than 1 lb.

East Texas casinghead gas, even after the extraction of the gasoline and butanes, has a very high heating value, which will cause the engine to run hotter and cause more ring and power-cylinder wear than will a gas of lower heating value. An analysis typical of the East Texas gas after gasoline and butane extraction is shown in Table 2 together with the B.t.u. content.

The effect of a high B.t.u. fuel has been partly overcome by lowering the fuel pressure. The usual pressure is 15 lb., but it has been found that if the fuel pressure is maintained between 6 and 7 lb., the machines will operate more satisfactorily. The fuel pressure is governed by a pilot-operated pressure-loaded reducing valve such as shown in Fig. 2. A pressure-loaded type of valve is more sensitive to adjustment than the usual spring- or weight-loaded regulator, and it is essential in a fuel-injection type of engine to have accurate fuel adjustment.

Air filters have been installed on all engines to keep as much sand and grit as possible out of the cylinders and thus reduce wear and cutting of the cylinder walls. The filters used are the cell type in which the air is drawn through a steel-wool packing. It is necessary to clean the cells twice a year by steaming out and washing in oil.

(Continued on page 90)

TABLE 1
Engine data

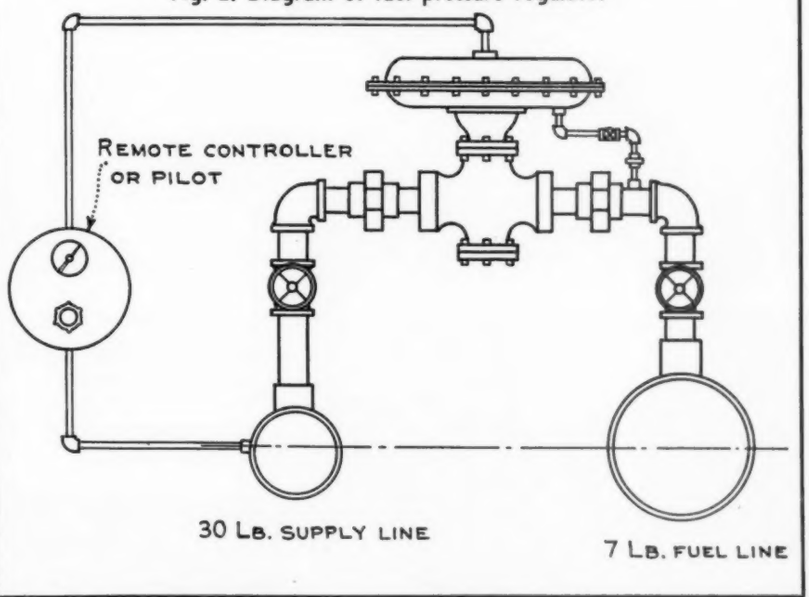
Rated brake horsepower	230
Revolutions per minute	200
Number of power cylinders	2
Dimensions of power cylinder	17 in. x 20 in.
Two-stage casinghead gas compressor	
Dimensions of low cylinder	21 in. x 20 in.
Dimension of high cylinder	10 in. x 20 in.
Piston displacement:	
Low cylinder	1594.23 cu. ft. per min.
High cylinder	354.41 cu. ft. per min.
Capacity per machine	1,020,000 cu. ft. per day
Single-stage propane compressor	
Dimensions	10½ in. x 20 in.
Piston displacement	391.67 cu. ft. per min.
Capacity per machine	3,700,000 cu. ft. per day

TABLE 2
Analysis of fuel gas—Sabine plant

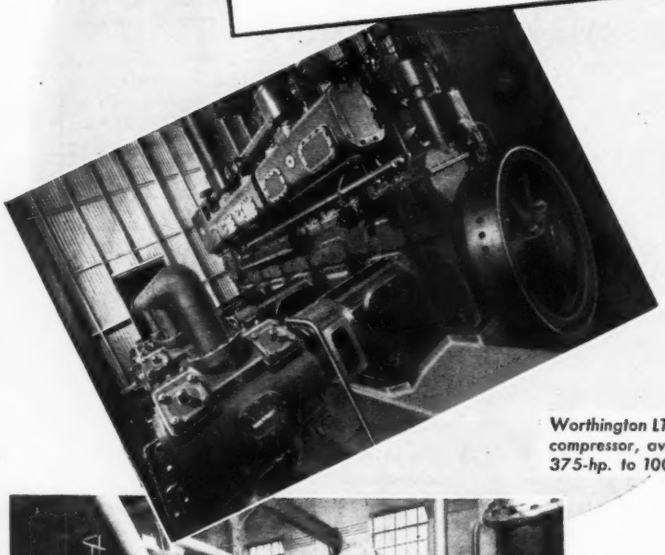
	Percent by volume
Methane	49.58
Ethane	22.51
Propane	27.73
Butane	0.18
	100.00

Calculated heat of combustion, 1601 B.t.u. per cu. ft.

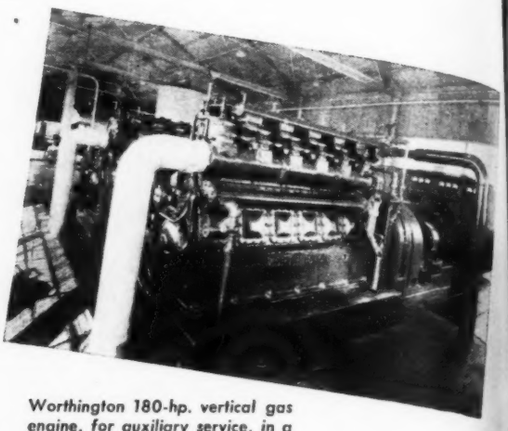
Fig. 2. Diagram of fuel pressure regulator



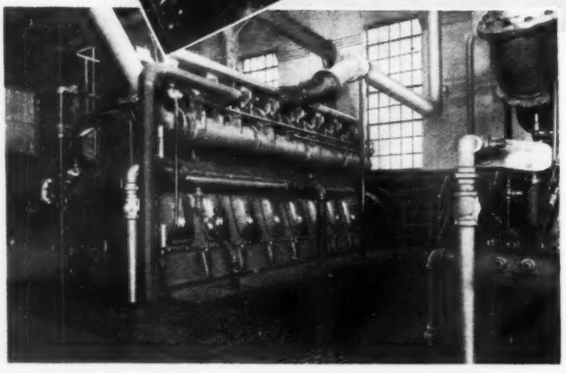
For Field ... Pipe Line



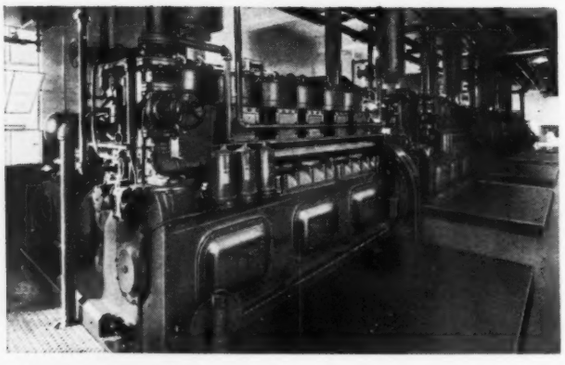
Worthington LTC angle gas engine compressor, available in six sizes, 375-hp. to 1000-hp.



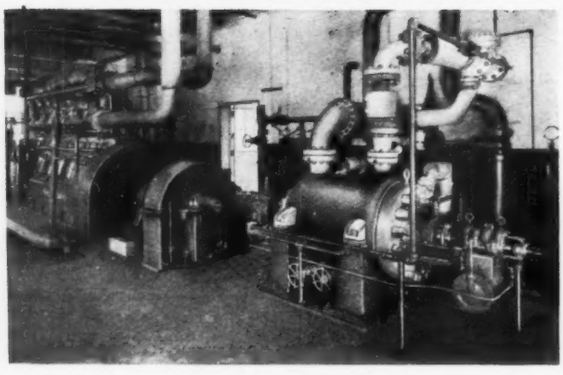
Worthington 180-hp. vertical gas engine, for auxiliary service, in a station of a large mid-western oil pipe line



One of two Worthington 8-cylinder 1000-hp. convertible gas-diesel engines, in general power service



Three 225-hp. and two 300-hp. Worthington LCE angle gas engine compressors, in a cracking plant of a mid-western oil refinery



Worthington centrifugal hot charge pump, driven by Worthington vertical gas engine, in an eastern refinery

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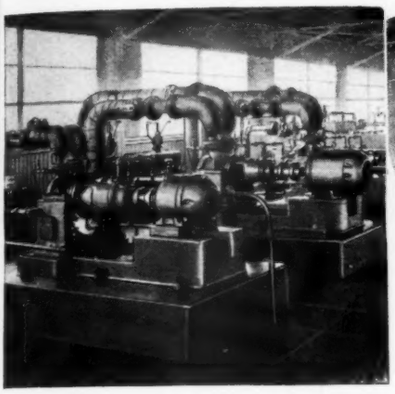
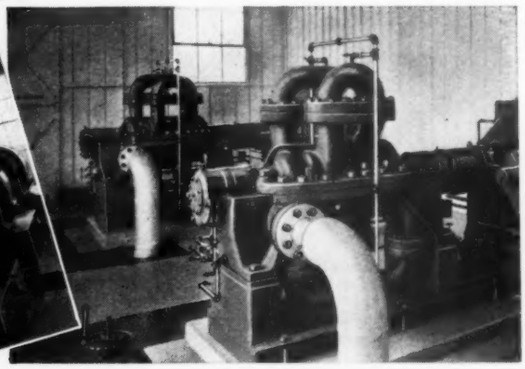
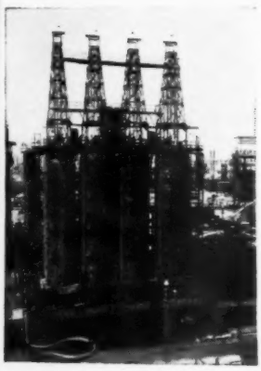




Two Worthington centrifugal pipe line pumps driven, through fire wall, by Worthington 280-hp. Diesel engines

Below—Worthington LCE angle gas engine compressor, with ammonia compressor cylinders, on refrigeration service in a lubricating oil dewaxing plant

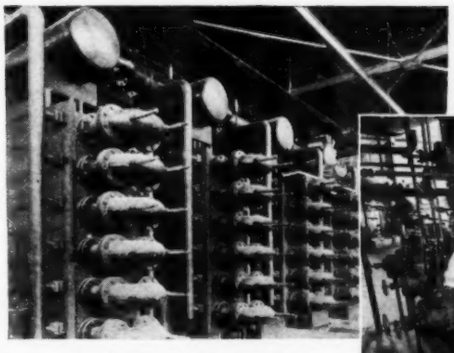


Above left—Two Worthington Type H centrifugal pumps handling hot oil

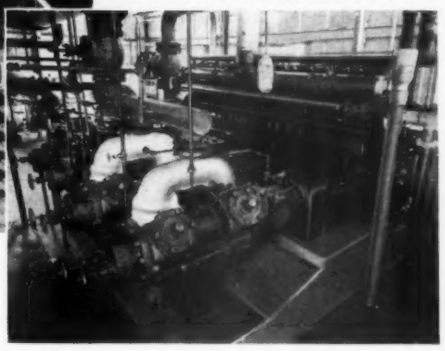
Above right—Three Worthington duplex pumps, electric motor driven, pumping cold oil at 1500 lb. per sq. in. discharge pressure

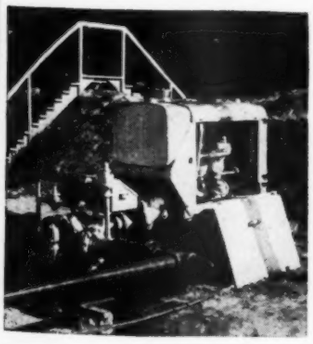
Left—Complete hydraulic decoking and coke transportation systems for economical removal and transportation of coke from coke chambers in oil refineries

Below left—Worthington rotary pump, gas-gasoline engine driven, in gathering service in the oil fields



Worthington-Carbondale chilling machines, for ammonia direct-expansion operation in a solvent dewaxing plant





Worthington HiVoL direct-acting pumps handling gasoline

Worthington centrifugal pumps in line, driven by Moore steam turbines, in oil refinery service

Worthington power pump driven by gasoline engine with Worthington Multi-V-Drive ... in oil gathering service

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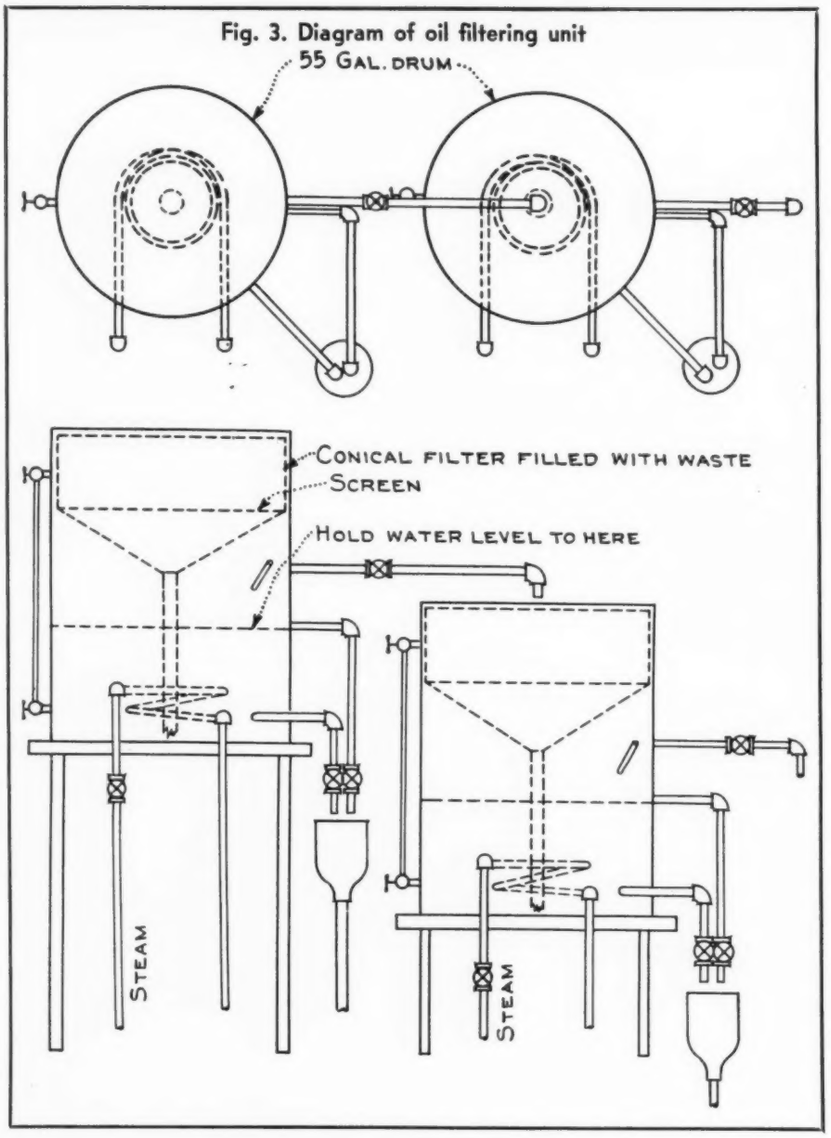
Fig. 3. Diagram of oil filtering unit



(Continued from page 87)

It has been found that the equipment operates better if a specific oil is chosen for each duty. Table 3 shows the properties of the oils used.

The oil used in low-compressor cylinders could be used in the high stage except for the fact that the intermediate gas is not cooled below 110°F., whereas the low-stage suction gas is about 80°F. The intermediate gas is not cooled below 110°F. as it is not desired to condense any of the gasoline fractions at this point that would condense at lower temperatures. This difference in suction temperatures accounts for using a higher flash and fire oil in the high cylinder.

When the oil from the crankcase is changed, a portion of the old oil may be recovered by passing it through a filter such as shown in Fig. 3. The temperature of the water in the drums is brought to approximately 180°F. and the used oil is poured into the first drum's filter. The oil is forced out the bottom of the funnel, rises through the hot water, and flows into the second filter, which operates in a similar fashion. The oil from the second filter is ready for use again. The yield is more than 90 percent by volume.

The operating and maintenance costs at the Sabine plant have been very economical. Table 4 lists the costs for the last four years. The increased labor in 1938 was caused by adding oilers to the operating crew. Prior to this time only one man was required on tour in the engine house, but with the installation of two additional machines, a helper was given to the engineer. In addition to duties as an oiler, this man looks after the boiler station, so part of his time should have been charged to this operation. The lubricating oil consumption may be higher than recommended and used by some companies, but it has been observed that the maintenance costs are kept at a minimum by not reducing the lubrication too low. It is the practice to make an annual inspection and thoroughly go over each machine, replacing any broken rings and making any other repairs, during the winter months when the load is light. All machines will thus be in good shape when the heavy load comes on during the summer.

There is considerable fluctuation in demand on the compressors both from day to day and from month to month. In the summer time, the higher temperatures cause higher gas-oil ratios, resulting in more gas than in the winter months. The machines must be maintained in condition so that they will handle such variations in gas volumes even though they are required to operate at more than their rated load for short periods of time, and they must process all available gas coming into the plant.

TABLE 3

Properties of oils used for lubrication—Sabine plant

	Power cylinder and crankcase	*Low compressor cylinder*	*High compressor cylinder*
Gravity, °A.P.I.	27.2	19 to 22	20
Flash, °F.	420	355	390
Fire, °F.	480	405	445
Pour, °F.	+5	—20	zero
Viscosity at 100°F.	585	300 to 324	730 to 780
Viscosity at 210°F.	65.5	46 to 49	58 to 61
Carbon residue, %	—	0.04	0.10

TABLE 4

Operation and maintenance costs per hp-yr.

	1936	*1937*	*1938*	*1939*
Operating labor	$2.35	$3.47	$4.58	$4.47
Operating materials	2.02	1.67	1.46	1.30
	$4.37	$5.14	$6.04	$5.77
Maintenance labor and materials	$1.75	$1.77	$1.49	$1.83
	$6.12	$6.91	$7.53	$7.60
Total oil consumption, hp-hr. per gal.			2220	2271

P 702.
P 967.6

Synthesis of Petroleum-like Hydrocarbons from Carbonaceous Material

The well-known process of manufacturing water gas has been developed in recent years as an important method of supplying gasolines in countries lacking in petroleum resources

By RAFAEL FUSSTEIG

IN recent years workers in science and technology in Germany have attacked with special assiduity the problem of producing petroleum-like products from solid fuels of domestic origin. The development of that branch of industry which deals with the synthesis of petroleum products from solid fuels has led to several important results in Germany. These methods that have already been applied in Germany in large scale operation may be said to point the way for all countries having a lack of natural resources. The most important method consists of conversion of solid coal into carbon monoxide, which is then submitted to a pyrolysis process in the presence of hydrogen under proper conditions, resulting in the formation of petroleum-like hydrocarbons.

This process may be carried out in two phases. In the first phase the carbon is transformed into the active monoxide, and in the second phase the carbon monoxide is split into oxide and carbon of two labile and active linkages, capable of entering into various reactions with hydrogen. According to Fischer and Tropsch, the changing of a solid fuel into an active form can be carried out by means of superheated steam, this process resulting in the splitting of the inactive solid hydrocarbon into carbon monoxide and hydrogen. Of course, this active gas, the so-called split gas, requires special purification for the removal of the traces of hydrogen sulphide. Besides, the content of the inert gases such as anhydrous carbonic acid, nitrogen, methane, etc., must be kept as low as possible, and should not exceed 15 percent.

It can be seen from the above that Fischer produces artificial stable carbon atoms having two active linkages, these being then transformed in the first reaction into $=CH_2$ molecules, which are then submitted to different polymerization processes to form varied hydrocarbons. In other words, all types of solid fuels suitable for the production of the split gas (water gas), can be used as raw material for the synthesis of gasoline.

RAFAEL FUSSTEIG

together with his family, is now in Lwow, Poland, having been obliged to leave his headquarters in Jaroslaw when that city was occupied by the German army—He hopes soon to come to the United States to establish his permanent residence—Prior to the outbreak of the war in Europe he was professor of petroleum technology in the Ecole Superieure Technique et Commerciale de Paris, Paris, France, and maintained an office as consulting petroleum engineer at Jaroslaw, Poland.

Research carried out in Germany by different investigators in connection with the development of this process shows that the following solid fuels can be used for the production of gases required for the synthesis: coke, bituminous coal, crude brown coal, brown-coal briquettes, wood, and peat, as well as natural gas, coke-oven gas, and the like. Many patents have been proposed for the production of water gas from the solid fuels as well as from natural gas. All these patents convert the starting material into a proper mixture of carbon monoxide and hydrogen.

Of course, the composition of the water gas depends to a high degree upon the operating conditions. For the production of synthetic gasoline, the proportion of carbon monoxide to hydrogen should be 2:1. But the use of different operating conditions changes the ratio of monoxide to hydrogen. Of course, the temperature and time as well as the catalyst are important. Temperature of 1100°-1200°C. can be considered as most suitable. The use of a proper catalyst prevents the formation of carbon. When a temperature lower than 1000°C. is used, the formation of methane and anhydrous carbonic acid can be observed. It is of great importance, therefore, to control the temperature during the operation. Likewise, the contact time plays a very important rôle in the synthesis of water gas.

The high temperature to which the reactants must be heated and the endothermic nature of the conversion reaction makes it essential to supply large quantities of heat. Supplying this heat constitutes the chief problem in the application of the steam conversion process. In modern apparatus designed for producing water gas, this heat is obtained by intermittently burning a part of the starting material in the reaction chamber, which is filled with refractory material. In the same manner natural gas can be converted into water gas. Without use of a catalyst, however, the decomposition of methane is incomplete, even at 1200°C. The use of nickel catalysts permits this reaction to proceed to completion.

In case solid coal is used for the production of water gas, it is generally conveyed from a "bunker" through a vessel in thin layers to a heat exchanger heated by the flue gas from the furnace. In this heat exchanger in addition

to the preliminary heating and drying of the coal, a certain primary decomposition of the material occurs. The gases and vapors formed in this exchanger enter into reaction with the solid coal. The temperature of the gases leaving the heat exchanger is approximately 400°C. These gases are then heated to about 1100°C. before being introduced to the reaction chamber wherein they enter into contact and reaction with solid coal. These gases must first be purified, however, before entering the reaction chamber. For this reason the tar vapors are first removed in an electrical tar separator, then the gases are desulphurized.

The purified gases in the reaction chamber form gases and vapors that correspond to the thermic decomposition of dry distillation at high temperatures. In the reaction chamber two phases are present: the gases and the incandescent coke at a temperature of about 1100°C. At the moment the coal is decomposed into gases and coke, steam is injected into the chamber.

Two reactions occur simultaneously: the coke enters into reaction with steam forming carbon monoxide and hydrogen, and the gases containing methane, etc., are transformed into water gas. According to the results of many investigators, one ton of a coal yields about 1750 cu. m. (61,800 cu. ft.) of water gas. One interesting method for producing water gas from solid fuels economically is that of Didier. Fig. 1 shows the flow of this process.

In the process, gasification proceeds continuously in chamber A, from the lower end of which, ash is continuously drawn-off. After passing through scrubber, B, the gases and vapors enter the regenerator, C, into the lower end of which is injected heated gas enriched with steam. As the gas current rises in the chamber, the gas is cooled by the reaction of the steam with the coal. The finished gas for the synthesis then leaves C and enters the carburettor chamber, D, which is filled with coal. The finished gas exits from the center of chamber, D, passes through the waste-heat boiler, E, and then enters chamber, F, wherein the hydrogen sulphide is removed. The finished water gas emitted from chamber F is now ready for further treatment in the synthesis of petroleum products.

The coal in chamber D is heated to a temperature of about 500°C. by a portion of the finished gas to effect a decomposition of the coal into gas, vapors, and water. This mixture passes overhead from chamber D to the electrical tar separator, G. After removal of tar, the gas is mixed with steam, heated in the regenerator C, and blown into the lower end of the carburetting chamber, D. The residual coke remaining in chamber D is withdrawn at the lower end of this chamber and directed to the top of the generator, A, by means of the blower, b. The coke is gasified in A and leaves the generator as producer gas.

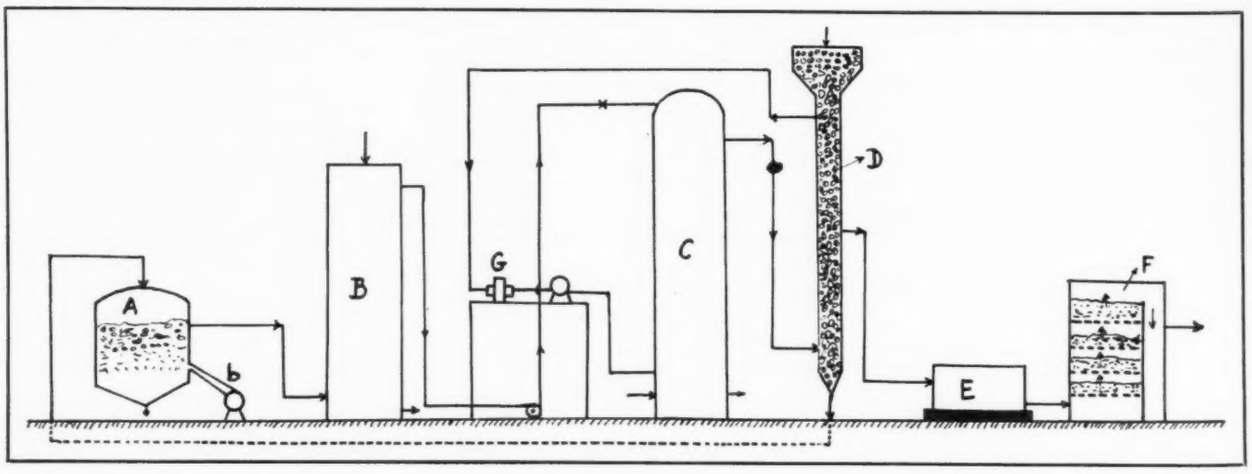
The gas for the synthesis, freed from sulphurated hydrogen, is first passed through a cleansing unit to remove carbon disulphide compounds. At a temperature of about 250°C. the sulphur is retained by means of a special purification mass. After purification, no carbon disulphide can be detected in the gas. The thoroughly purified gas is then ready for further treatment. The water gas when submitted to proper operating conditions forms liquid hydrocarbons. Of course, the hydrocarbon composition obtained in the pyrolytic synthesis of the water gas depends largely upon the pressure, temperature, catalyst, contact time, and the ratio of hydrogen to carbon monoxide.

The volume of hydrogen in the water gas is an important element in the formation of hydrocarbons. When carbon monoxide and hydrogen are present in the water gas in the proportion of 1 to 3, the quantity of olefinic hydrocarbons formed will be less than when the proportion is 1 to 1. According to Fischer and Tropsch, water gas containing 1 part carbon monoxide and 1 part hydrogen yields, under certain conditions, 58 percent olefinic hydrocarbons. Under the same conditions, however, a ratio of 1:2 yields 34 percent of olefins, and when the ratio is 1:3, under the same conditions, only 11 percent of olefinic hydrocarbons will be obtained.

These phenomena are of great importance in the synthesis of petroleum products because they make it possible to regulate the proportion of the hydrocarbons formed. As mentioned, the amount of hydrogen in the split gas influences the formation of olefinic hydrocarbons; that is, the more hydrogen in the split gas, the smaller the yield of olefins. As the gas when split contains 3 parts of hydrogen and 1 part of carbon monoxide, it is evident that only a small amount of olefins would be formed. Thus, according to the method of Fischer and Tropsch, gas split from natural gas is only valuable in forming saturated hydrocarbons because of the great excess of hydrogen.

As mentioned, temperature and pressure play a very important part in the removal of the hydrogen excess from the water gas and in the reaction between the unstable carbon monoxide and hydrogen. Of course, the temperatures employed depend upon the kind of catalysts used. For example, the

Fig. 1



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synthesis of gasoline-like hyrocarbons requires a temperature of 250°C., when iron is used as a catalyst. When cobalt is used, a temperature of 180°C. is sufficient for the same reactions. Gas mixtures rich in hydrogen require the use of lower temperatures, while mixtures poor in hydrogen must be submitted to higher temperatures. Increase in pressure causes the formation of split hydrocarbon molecules, while increase of temperature favors the formation of methane and hydrogen. Table 1 gives a summary of the various factors and their effect on the products obtained.

TABLE I

1.	Increase in pressure	Synthol, sp. gravity—0.8829 at 20 °C.
2.	Increase in hydrogen	Methane, therefore the decrease in temperature is necessary.
3.	Decrease of hydrogen	Olefin hydrocarbons.
4.	Increase in temperature	Methane and carbon deposition.
5.	Use of the catalyst	The increase of the desaturation.

From the above, it is evident that the pyrolysis of water gas permits wide latitude in the choice of operating conditions, resulting in varied reactions and, consequently, different products. Under certain operating conditions, two hydrogen atoms of water gas enter into chemical reaction with a molecule of carbon monoxide, the oxygen being split from the nucleus at the same time. Thus, $=CH_2$ molecules are formed in the first phase; in the second phase these $=CH_2$ molecules are converted into different hydrocarbons, and the oxygen split from the nucleus is converted to water.

This phenomenon leads to the formation of liquid consisting of two layers: the under layer is water resulting from the reaction and the upper layer contains an oil and heavy gasoline. These layers are in the proportion of 1:1 or 2:1. The closer the oil-water ratio approaches the proportion of 1:1, the better will be the yield of the liquid products. The oil separated from the gasoline contains certain amounts of solid paraffinic hydrocarbons having a melting point of 50°-60°C., the volume of these compounds being dependent on the catalyst, pressure, and temperature.

All products obtained in this process contain paraffinic hydrocarbons and mono-olefins. Fischer[1] has carried out the pyrolysis of a water gas with a content of 29 percent carbon monoxide and 58 percent hydrogen using cobalt as a catalyst, and obtained the following results:

	Melting point, °C.	Boiling range, °C.	Volume percent	Content of olefins, percent
Gas-oil	.....	below 30	4	50
Gasoline	.....	30-200	62	30
Oil	.....	over 200	23	10
Solid paraffin wax from the oil	50	.....	7	.....
Hard paraffin wax from the contact	70-80	.....	4	.....

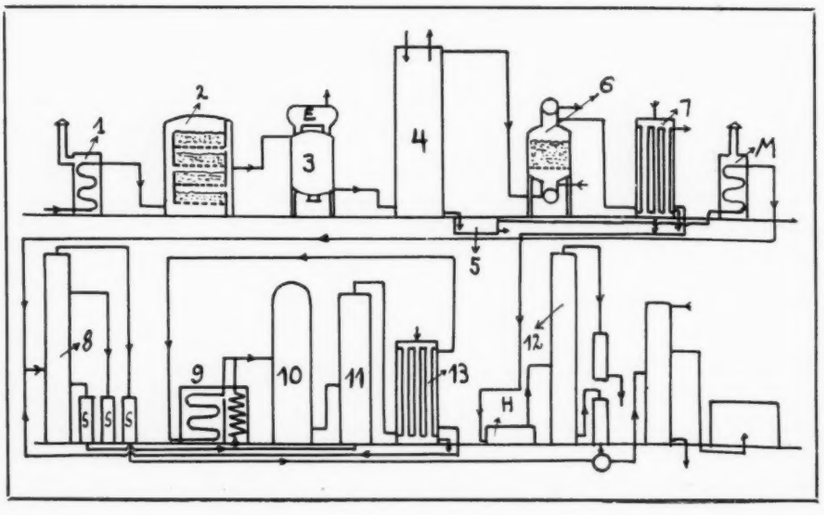
From these figures it is evident that the gasoline is the principal product; the gas-oil and paraffin wax yields are very small. This liquid mixture from the pyrolytic process has been named by Fischer "kogasin," the separated fraction of higher-molecular hydrocarbons from kogasin, having the name "kogasin II." This kogasin II contains certain amounts of paraffin wax; after separation, a Diesel oil of high quality is obtained. The latter oil has a uniform aliphatic character and a consequent favorable combustion quality, and other desirable qualities of a good antiknock Diesel oil. Besides, it shows a high hydrogen content, which contributes to a smaller consumption in the Diesel motor than the gas oil.

Fischer has proposed a method that is already in use in many factories in the world. Fig. 2 illustrates the flow of this synthesis.

In the process, the thoroughly purified gas is introduced into a heater, 1, in which it is heated to a proper temperature. The heated gas is directed to chamber, 2, to remove all traces of carbon disulphide. From 2 it goes to the contact retort, 3. Here the gas comes into contact with a proper catalyst and is converted into gasoline at a pressure of about 1500 mm. of water (2 lb. per sq. in.) at a temperature of 180°-195°C. The heat of reaction liberated by the formation of gasoline is removed in the evaporator, E, the tubes of which are maintained at a pressure corresponding to the reaction temperature. This heat, which represents a considerable percentage of the heat of combustion of the gas used for the synthesis, is converted into steam, which is utilized in the process itself. The hyrocarbons and the unconverted gas exit from the lower end of the contact retort, 3, then enter the 3-stage condenser, 4, cooled by a water spray. Here the separation of hyrocarbons and steam from the unconverted gas takes place. The cooled unconverted gas is then passed to the activated charcoal vessel, 6, wherein the light oil is adsorbed. The light gasoline is recovered in vessel 6 by means of steam. Thus a large quantity of gaseous hyrocarbons, which cannot be condensed by water cooling, are recovered, consisting principally of propane, butane, and similar hydrocarbons. The separation between the light liquid hydrocarbons and propane, butane, etc., occurs in the condenser, 7. The gaseous hydrocarbons pass overhead from the condenser; the liquid hydrocarbons are drawn off at the lower end of the condenser and are directed to the heater, H. From H, the heated oil goes to the

[1] *Brennstoff-Chemie*, 1935, p. 16.

Fig. 2



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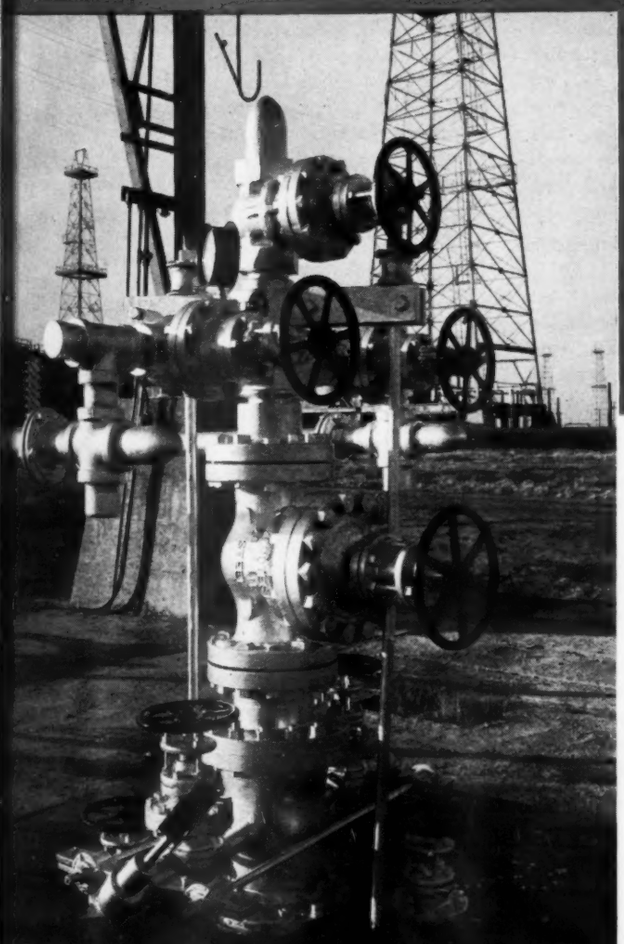

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stabilizing column, 12, in which the gasoline is stabilized.

The synthetic oils condensed in condenser 4 go to the separating pit, 5. In the latter vessel, water and oil are separated. Then the oil passes through the heater, M, through the 3-stage distillation column, 8, and then through the separator, S, in which the separation between the residue, Diesel oil, and gasoline occurs. The residue must then be submitted to a cracking process to increase the gasoline yield. Of course, this cracking may be executed in various ways. In Fig. 2, the process shown is "true-vapor-phase cracking."

The cracking is conducted so that the residue separated in S may be delivered in the vapor phase to the oil heater, 9, to be heated to the desired cracking temperature. Under a pressure of about 12 atmospheres the starting material flows to the reaction chamber, 10, to undergo decomposition. At the same time a circulating gas is introduced into the reaction chamber as a means of controlling the reaction temperature. The cracked gases then enter the fractionating column, 11, from which they are passed to the condenser, 13. The heavy and light components are separated and the former are returned to the cracking vessel. The light gasoline is then stabilized by means of superheated steam.

It should be noted that only 60 percent of water gas enters into the reaction during a single pass through the synthesis-reaction chamber. The remaining 40 percent of unconverted gas still contains considerable heat. To utilize this heat, therefore, the residual gas is directed to a second synthesis-reaction chamber wherein further reactions result in the formation of additional gasoline. After the second phase of synthesis (not shown in Fig. 2), the hydrocarbons are removed from the unconverted gas by cooling and absorption. The residual gas, which now contains a large percentage of inert components, is used for heating purposes.

As mentioned earlier, the pressure and catalyst are important in the synthetic process. Under similar conditions, but using varied pressures, quite different products will be obtained. Under a pressure of 150 atmospheres, water gas will be transformed into "synthol," which is a mixture of alcohol, aldehydes, and hydrocarbons. Under the same conditions but at atmospheric pressure, "kogasin" will be obtained. The yield of "synthol" will increase in the presence of iron chips; "kogasin" is best produced in the presence of iron activated with copper and small amounts of alkali.

It is important in the water gas reaction that the synthesis gas be free from organic and inorganic sulphur. The permissible maximum limit of sulphur content in the gas mixture is 2 mg. per cu. m. (0.87 grains per 1000 cu. ft.). Hydrogen sulphide can be removed in iron oxide boxes by the ordinary method employed in gas works, but the elimination of organic sulphur compounds requires supplementary treatment. Both nickel and cobalt catalysts, which play an important rôle in the synthesis of petroleum products from water gas, are so readily poisoned by sulphur compounds that rigorous purification of the gas is essential. The "Studien und Verwertungs, G.m.b.H." (English patent 452,417) have stated that iron oxide, to which not less than 10 percent of alkali carbonate has been added, can be used to decompose these organic compounds and to retain the sulphur formed. This absorbent is very active in the fresh state at temperatures of 200°-230°C., but after aging, this absorbent may act at a temperature of 300°C. After a certain time, therefore, the operating temperature must be increased. The same company proposes in a later patent a combination of the abovementioned reagent with cobalt sulphide, which acts at a temperature of 400°C. The advantage of this patent is that the bulk of the organic sulphur compounds can first be broken down catalytically and the hydrogen sulphide removed in the iron oxide box, so that the life of the high-temperature absorbent can be greatly extended. Recently the "Ruhrchemie, A. G." has stated that the gradual impregnation of the catalyst by high-melting wax decreases its efficiency. It has often been observed that the contact mass will absorb 150 percent of its own weight in wax having a melting point of about 80°C.

Of course, this phenomenon takes place only if the factors are conducive to the formation of paraffin wax. When these factors are present, it is more convenient to suspend a proper catalyst in the medium through which the gas is directed. There are many patents proposing the manufacture of paraffin wax from water gas. The "I. G. Farbenindustri, A. G." proposes in one patent (English patent 458,035) the use of the exterior of the tubes, through which the cooling medium is circulated, as a catalytic surface. The tubes are etched with acids, to which solutions of such promoters as uranyl, copper, magnesium, or potassium nitrates are added. When a gas mixture of 50 percent carbon monoxide and 50 percent hydrogen under a pressure of 100 atmospheres is used, reaction occurs at a temperature of 368°-412°C. The same company proposes another patent (English patent 449,274) in which paraffin wax is also formed from water gas. Carbon monoxide and hydrogen under a pressure of 50 atmospheres are heated with anthracene oil to 250°C. A catalyst consisting of zinc oxide, magnesia, and iron is suspended in the oil.

Fischer and Pichler[2] have stated that increased yields of the product may be obtained by dividing the process into stages. When the products of the reaction are condensed after the first stage, the yield may be increased from 110 to 125-130 grams of hydrocarbons per cu. m. (0.68 to 0.78-0.81 lb. per 1000 cu. ft.) of gas. The best results are obtained when the temperature of the catalyst in the second stage is maintained at 5°-10°C. above that in the first. The two-stage operation allows a greater proportion of the catalyst to work at full efficiency. Besides, it permits a higher throughput of gas, which gives a higher percentage of olefin hydrocarbons in the products. This method is patented by two companies (1) Robinson-Bindley process—English patent 386,982; and (2) Studien und Verwertungs, G.mb.H.—English patent 454,948.

Reviewing the above, it may be concluded that the synthesis of gasolines, oils, paraffin waxes, etc., results from a combination of various factors. The stable carbon monoxide with two very active linkages is split into a carbon atom of two active linkages, and oxide, the former entering immediately into chemical reaction with the hydrogen of the water gas, forming the $=CH_2$ molecules. These $=CH_2$ molecules can then be made the basis of the formation of various hydrocarbons. By altering the different factors, polymerization, isomerization, disintegration, and alkylation reactions may be variously obtained, resulting in the formation of correspondingly different hydrocarbon mixtures. The hydrocarbons produced in the synthesis consist predominantly of straight-chain paraffin hydrocarbons and mono-olefins although benzol, toluol, and naphthalene have been detected in amounts of 0.1 percent. The proportion of the olefins in the oil is greater when cobalt catalysts are used instead of nickel, and may be further increased by reducing the proportion of hydrogen to carbon monoxide below 2:1. Finally, it should be mentioned that the percentage of unsaturated hydrocarbons in any fraction decreases with the increase in boiling point.

[2] *Brennstoff-Chemie*, 1936, p. 24.

Deepening and Completing a Well in the Lisbon Field, Louisiana—A Study in Modern Coöperative Practice

Part 4

By PAUL D. TORREY, Geologist, The Sloan and Zook Company
and
FRANK H. MILLER, Petroleum Engineer
Lisbon Exploration Company, Inc.

DRILLING (Continued)

(b) Mud fluid volume. It has been determined from numerous tests that a fluid circulation of 50 gal. (approximately 6 2/3 cu. ft.) per min. per in. of hole diameter will give consistently satisfactory results under normal drilling conditions. In the case of the Vaughn well this would mean that about 41.5 cu. ft. of mud fluid should have been circulated each minute to provide for efficient drilling. The highest fluid volume circulated, however, was 25 cu. ft. per min., and near the bottom of the hole this had declined to about 17 cu. ft. per min. The pumps employed were therefore delivering in the lower part of the hole less than half of the mud fluid that should have been available for effective drilling. It will be noted in Fig. 8 that the decline in the rate of penetration corresponds directly with the decline in the rate of mud fluid circulation. Pumps of larger capacity certainly would improve the rate of penetration, and this is particularly true in the Cotton Valley formation where the shales do not grind down into mud but rather are brought to the surface as coarse chips.

(c) Weight on bit. An average of about 5 points of weight with 6 drilling lines was carried on the bits during the drilling of the Vaughn well. The weight carried was somewhat lighter in the upper sections drilled when higher rotating speeds were employed, and it was increased as the rotary speed was decreased in the lower part of the hole. A good average bit weight for ordinary drilling is one-half point per in. diameter of bit, which would amount to a little more than 3 points for a 6¼-in. bit. It is very likely that the severe wear of the cone bearings, which took place at several different depths, may be attributed to overloading. Lighter weight combined with higher rotary speeds should improve materially the performance of the 6¼-in. bits.

(d) Summary of certain mechanical factors. It is impossible to segregate the relative effects of rotary speed, mud fluid volume, and weight on bit with rate of penetration until additional wells are drilled in the area. In the small-size hole it can be concluded that increased rotary speed, increased mud fluid circulation, and decreased average weight carried on the bit should improve materially the rate of penetration and bit performance. To be more specific, it can be stated that at an average rotary speed of 100 r.p.m., a mud fluid circulation of from 40 to 42 cu. ft. per min., and a weight of from 3 to 3.5 points, using 6 lines, the average rate of penetration, as indicated in Fig. 8, might be doubled in drilling a 6¼-in. diameter hole. In addition the lighter weight carried on the bit should improve bit performance in reducing excessive bearing wear, thus eliminating several trips for bit replacement. This rule cannot be applied to larger diameter holes. With larger bits and heavier drill pipe, still higher rotating speed and greater weight on bit undoubtedly can be used to advantage, but this correspondingly will require a faster circulation of mud fluid.

Photographs and biographical sketches of the writers of this article can be found on page 155 of the February issue of *The Petroleum Engineer*, in connection with Part 1.

11. Depth measurements. Reistle and Sikes,[16] in their able discussion of well-depth measurements, state in part: "Well depths cannot be measured by any procedure wherein all errors can be determined and corrected; therefore, some acceptable substitute for absolute depth must be used. It is apparent that, for correlation of formations and the selective completion of wells, relative depths which may be accurately reproduced are as satisfactory as absolute depths. Of more importance is the ability accurately to locate at will any subsurface point in the well, using drill pipe, sand line, special measuring devices, casing or tubing."

After due consideration, two methods of depth measurement were employed in deepening the Vaughn well, and as usual a tally was kept of the drill pipe as joint after joint were added during the deepening operation.

The first method of measurement consists of measuring the drill pipe as it hangs suspended under tension from the elevators during the course of pulling it from the hole. Before the pulling of the drill pipe is begun, the bit is placed on bottom carrying 4 to 5 points weight. The pipe is then picked-up until the weight indicator shows that the bit is barely touching bottom, and after measuring the footage on the kelly and placing the latter in the rat-hole, the first stand of drill pipe is pulled to the level of the derrickman's platform. The derrickman holds one end of a 100-ft. steel tape on which the individual feet are graduated in one-hundredths of a foot. The end of the tape is securely welded to an elliptical-shaped, high-tensile, spring-steel wire tape-holder that will fit snugly into the tool-joint box and hold the zero mark of the tape tightly against the top of the box. After the derrickman inserts the tape-holder into the box the drill pipe is elevated until the tool joint at the bottom of the stand appears above the level of the rotary table. The lower end of the tape is held by an assistant on the derrick floor and when the bottom tool

[16] "Well Depth Measurements," C. E. Reistle, Jr., and S. T. Sikes, Jr., A.P.I. Division of Production, Eighth Mid-Year Meeting, Wichita, Kansas, May 25, 1938.

TABLE 15
Depth measurements on Vaughn No. 1 well

Pipe measured	Measured depth, ft.	Calculated depth, ft.	Difference, ft.
Drill pipe.....	5313.62	5313.00	0.62
Drill pipe.....	6790.86	6790.48	0.38
Drill pipe.....	8268.55	8270.00	1.45
Tubing.....	8866.18	8868.39	2.21

joint of the stand makes its appearance he pulls the tape taut along the side of the pipe, maintaining as constant a tension as possible for each successive measurement. The length of the stand is read and called to another assistant who makes a record of the length of each stand as it is pulled. After the measurement has been made, the drill pipe is lowered to permit the derrickman to remove the tape-holder from the box. The pipe is again raised so that the tool joint can be broken, and the stand is then stacked in the derrick. This procedure is repeated for each stand until all of the pipe has been pulled from the hole.

The measurement of drill pipe under tension as it is being pulled from the hole is believed to be the most accurate method of well-depth measurement that may be used without too much loss of time. This method takes into account the elastic stretch of the drill pipe resulting from its own weight, and it also takes into account the elongation of the pipe due to thermal expansion. Possible errors that may enter into measurement by this method result from variations of tension placed on the tape, and from wind action blowing the tape away from the pipe. Obviously a still day is most desirable for measurement by this method.

Depth measurements were checked by the measurement of drill pipe under tension on three occasions, and by the measurement of tubing under tension on one occasion. The results of these measurements are given in Table 15.

It will be noted that the discrepancy in measurement apparently increases with depth; there are, however, several distinct and separate explanations for this. The error in the original depth measurement may be due to the fact that the original total depth was reported in even feet. The second and third checks were quite satisfactory, the maximum error in the third check amounting to only 0.0175 percent. In the fourth check, using tubing measurements, the total depth had been calculated as being at the top of a tool that had been lost in the hole. There is a very good possibility that some of the parted cable along with cavings may have been packed down on the top of the tool, thereby decreasing the depth of the hole by 1 or 2 ft., and thus accounting for the difference in measurement.

The second method of depth measurement employed on the Vaughn well consists of measurements that accompanied the electrical surveys made at three different depths during the course of deepening the well. In addition, checks of total depth were made before the casing was perforated for production tests. The measurements are listed in Table 16.

It will be noted that the electrical log measurements are consistently shorter than depths ascertained by the measurement of drill pipe, casing, and tubing, but it can be pointed out that the depth to the top of the Vaughn sand checked exactly in two separate electrical surveys. Thus, although depth measurements by the two different methods do not correspond, the recording of the depth of the top of the sand on the electrical log is absolutely consistent.

In order to eliminate, as much as possible, errors in depth measurements made with a wire cable, such as: stretch due to acceleration forces while running and pulling the electrode, variations in suspended load between electrodes and gun-perforating devices, errors in the counting mechanism, and wear of the measuring sheaves, the electrode cable is measured under tension as it is run into the hole, and is flagged at 100-ft. intervals. This permits a check of depth to the nearest 100-ft. mark and facilitates checking the hole depth every time a gun-perforating device is run.

The difference between the depths measured while perforating and depths determined by the measurement of pipe is less than the difference between electrical log depths and pipe measurements. This may be due to the elastic constant for the cable being determined for the heavier perforating gun, and also to the fact that the perforating guns were run inside of casing where only a small volume of cavings could accumulate at the bottom of the hole thus decreasing its measurable depth. Furthermore, it should be pointed out that the discrepancy in depth, as illustrated in the first electrical survey, was constant in measuring both the bottom of the 7-in. casing, and the bottom of the hole.

The accumulation of cavings and cuttings at the bottom of the hole, even after thorough mud circulation, presents a problem in depth measurements when a wire cable is used, which cannot very well be overcome. The bottom of the hole, or rather the point of contact, can be determined readily by electrical logging devices and gun-perforators, but it is obvious that if the hole has been filled for any distance by cavings the total depth cannot be determined. As long as the measurements are consistent, even though discrepancies do exist, there would appear to be little chance for serious error in perforating the casing at depths indicated by electrical surveys; particularly if the same cable is employed for running both instruments and the total depth of the well is checked on each run of the perforating gun.

12. Coring. Seventeen cores were taken during the course of deepening the Vaughn well. These are listed in Table 17.

The time required for each core includes the time involved in pulling the drill pipe, removing the bit, putting on the core barrel, running the core barrel to bottom, actual cutting of the core, pulling the core barrel, removal of the core, replacing the core barrel with a new bit, running the bit down to the shoulder, and reaming the hole to bottom. The average time required for each core was 957 min. or 15.9 hours.

Cores were taken in the Travis Peak formation for geologic information and to ascertain the productive possibilities of several sands. Cores were taken in the Cotton Valley formation primarily

TABLE 16
Comparison of pipe depth measurements and wire-line depth measurements on Vaughn No. 1 well

Object of measurement	Pipe depth, ft.	Wire-line depth, ft.	Difference, ft.
Bottom of 7-in. casing	5291*	5285	6
For electrical survey	6988†	6982	6
For electrical survey	8507†	8503	4
For electrical survey	8900†	8895	5
For gun-perforation	8878*	8877	1
For gun-perforation	8865‡	8863	2
For gun-perforation	8865‡	8862	3
Depth, top Vaughn Sand—2nd electrical survey		8446	
Depth, top Vaughn Sand—3rd electrical survey		8446	

*Casing measurement.
†Drill pipe measurement.
‡Tubing measurement on top of lost tool.

TABLE 17
Coring record of Vaughn No. 1

Core no.	Depth, ft.	Footage cored	Footage recovered	Time required, min.	Size core-cutter head, in.
1	5405.5–5420.0	14.50	14.50	583	5¾
2	5420.0–5439.0	19.00	19.00	949	5½
3	5631.5–5642.5	11.00	6.25	547	5½
4	5984.2–6002.2	18.00	11.50	780	5½
5	6158.0–6170.0	12.00	9.25	715	5½
6	6925.0–6943.0	19.00	14.20	839	5½
7	8225.1–8235.3	10.20	10.20	941	6
8	8252.0–8270.0	18.00	11.75	1384	6
9	8360.0–8373.0	13.00	12.00	549	6
10	8373.0–8384.0	11.00	10.75	1191	5¾
11	8388.0–8403.0	15.00	13.75	1342	6
12	8464.0–8480.0	16.00	11.00	1396	5¾
13	8729.0–8745.0	16.00	14.50	1276	5¾
14	8817.3–8828.7	11.40	11.40	975	5¾
15	8828.7–8838.0	9.30	8.30	711	5½
16	8838.0–8848.0	10.00	8.30	911	5¼
17	8858.7–8871.0	12.30	7.40	1154	6
	Total.....	235.70	194.05	16,243	

Summary:
Percentage core recovery, 82.33.
6-in. cutter-heads used, 5.
5¾-in. cutter-heads used, 5.
5½-in. cutter-heads used, 6.
5¼-in. cutter-heads used, 1.
Total time involved in coring, 16,243 min. (271 hr.) (11.3 days).
Average time required for each core, 15.9 hr.

to determine the productive possibilities of the Lower Marine sands.

A conventional core barrel with hard-rock cutter-heads was used. When cores were taken in sequence the outside diameter of the core cutter-head was reduced ¼ in. for each successive run.

As shown in Table 14, it will probably be necessary to take only 8 cores to determine the productive possibilities of the Lower Marine sands to a depth of 3587 ft. below the Pettit lime in future deep drilling in the Lisbon field. This will provide a saving of 9 cores. The actual time saved will be slightly more than 5 days at the rate of 13.38 hours per core. A lower figure has been used than the total average figure of 15.9 hours per core inasmuch as most of the cores eliminated were taken in the Travis Peak formation at shallower depths than the Lower Marine cores. Nine core cutter-heads also will be saved and it is very reasonable to believe that at least 3 bits will be saved in less reaming. The wear on the bearings of small bits while reaming is usually much more severe than in actual drilling. The saving in bits due to less coring, from the standpoint of bearing wear, has been taken into account in Table 14.

A graphical analysis of all coring during the deepening operation is given in Fig. 8. The average rate of penetration in coring was about 18 min. per ft., the average rotating speed while coring about about 48 r.p.m., and the average weight carried on the core cutter-head was 3 points. Core recovery was generally better when not more than 15 ft. of formation was cut. This is particularly true in broken formations and in the Lower Marine sands where bearing wear of the cutters was quite severe. To prevent loss of core while the core barrel was being pulled from the hole, the joint at the bottom of each stand was broken manually rather than by the rotary table.

13. Fishing jobs and suggestions for their prevention. A description has already been given of the recovery of the parted 7-in. casing, and of the running and engagement of new 7-in. casing in the upper part of the hole. This part of the report will be devoted to a discussion of the difficulties that were experienced in freeing stuck drill pipe, fishing for twisted-off drill pipe, and fishing for cones that were lost in the hole.

On September 2 and 3, the drill pipe was stuck for a period of 12 hours at a depth of 6158 ft. The pipe was stuck while the bit was at least one joint off bottom, and while the mud was being circulated for the purpose of recovering drill cuttings from the bottom of the hole. While the mud was being circulated the drilling engine stalled suddenly and thus stopped the rotation of the drill pipe in the hole. When the engine was started it was found that the pipe was stuck although circulation could still be maintained. Crude oil (56 bbl.) was introduced through the drill pipe and shortly thereafter the pipe was freed. It is believed that very soft sand and shale caved into the hole, at the point at which the pipe was stuck, in such quantity that the pump was unable to circulate mud fluid fast enough to carry the cavings away after the engine had stalled, thus sticking the lower part of the drill pipe near the bottom of the hole.

On September 22, while drilling in very hard quartzitic sand at a depth of 7680 ft., the drill pipe twisted off, 4 stands from the bottom of the hole. An "A" type bit was being used owing to temporary inability of obtaining "B" type bits. At it was later discovered, all three cones were sheared from the bit. The free drill pipe was pulled from the hole and then run back with an overshot on the lower end, which engaged tightly with the upper end of the four stands of pipe. Finding the drill pipe was stuck, 65 bbl. of crude oil was pumped down through the drill pipe. The stuck pipe after being washed for about 30 hours finally came free, and was pulled from the hole leaving all three cones on bottom. Slightly more than two days were required to fish the lost cones from the hole, the method employed being to drop a metal basket on the end of the drill pipe for a distance of about 5 ft. The weight of the drill pipe on top of the basket was sufficient to collapse its lower end thus holding the cones and preventing them from being dropped while the pipe was being pulled out of the hole.

It is believed that this twist-off and fishing job could have been avoided if the proper type of bit had been available. The cones, when recovered, showed that they had been worn down to nothing more than smooth nubbins, notwithstanding the fact that the bit had made only about 6½ ft. of hole. A weight of 4.5 points and a rotary speed of 85 r.p.m. were being carried at the time of the twist-off. After the cone teeth had been worn off, undoubtedly the cones began to drag thus weakening the bearings and causing them to shear. When this occurred the bit was stuck due to the loose cones in the hole, and this in turn resulted in the twist-off. By the time the free pipe had been pulled from the hole, and then run in again with the overshot on the lower end, the drill pipe remaining in the hole had been securely stuck due to caving from the wall of the

TABLE 18
Time consumed in various operations connected with deepening the Vaughn well from 5313 to 8900 ft.

Operation	Time consumed, days
Recementing surface casing, pulling parted 7-in. casing and running new 7-in. pipe in hole	5.0
Circulating mud fluid for samples	1.0
Pulling and running drill pipe for bit replacement	16.7
Fishing	5.4
Repairs on rig	1.0
Fighting attempted blow-out	0.5
Mud and hole conditioning	0.7
Coring and reaming	11.3
Electrical surveys	0.8
Shut-down time	1.2
Actual drilling	29.4
Total	73.0

TABLE 19

Estimated saving in time in future deepening of wells in the Lisbon field in comparison with the record of the Vaughn well

Operation	Time consumed, days
Recementing surface casing, etc.	5.0
Pulling and running drill pipe for bit replacement	2.0
Fishing	5.4
Blow-outs	0.5
Coring and reaming	5.0
Shut-down time	1.2
Increased efficiency of drilling due to larger pumps, higher rotating speeds, and better bit performance	7.3
Total	26.4

hole. A total of 109 hours was spent on this fishing job.

In the last fishing job on the Vaughn well, on September 30, one cone from a "B" type of bit had been lost at a depth of 7759.5 ft. This bit had made only 1½ ft. in extremely hard, quartzitic sand, and had been in the hole for slightly over 6 hours when it was decided to pull the pipe and put on a fresh bit. The weight carried was 4.7 points and the rotary speed was 30 r.p.m. while the bit was drilling. When the bit was brought to the top of the ground it was found that one cone had sheared off. The metal basket was immediately run in and the lost cone successfully recovered on the first trip. The cones remaining on the bit and the lost cone were not worn as much as the cones of the "A" type bit, previously lost. An inspection of the lost cone and the bit revealed the possibility of a defective bearing, although it must be admitted that the bit was probably run longer than it should have been under such severe conditions. Eight hours time were lost in this fishing job.

A total of 129 hours or almost 5.4 days was spent on these various fishing jobs. Probably much of this time could have been saved and in future operations these difficulties avoided if the proper type of bit is used. The hard, quartzitic sands in the lower part of the Travis Peak formation will always present a troublesome problem, and great care must be exercised in drilling them. The stuck drill pipe at 6158 ft. and the lost cone at 7759.5 ft. can probably be better classified as unavoidable accidents that might occur on any drilling well. Larger capacity pumps will probably help considerably in eliminating stuck drill pipe due to caving of the wall of the hole in future deep drilling in the area, and drill pipe equipped with special joints should help to prevent twist-offs, should the bit become stuck on bottom.

14. Reconditioning hole for the running of casing. Notwithstanding the verticality of the Vaughn well and the general good condition of the hole, it was realized that the margin of clearance between the bore hole having a diameter of 6¼-in. and the 5-in. O.D. casing was very small. It was concluded, therefore, that every possible precaution should be taken to condition the hole before beginning to run casing. After the last electrical survey was made, a fresh bit was run to the bottom of the hole, thoroughly reaming the filter cake from the face of all sands on the way down. In the meantime the mud was carefully tested and 6 sacks of material were added to reduce its viscosity. The mud was circulated for 5 hours in order to stabilize its weight and viscosity. The drill pipe then was pulled from the hole and stacked in the derrick; after the blowout preventer was changed to permit the passage of 5-in. pipe, the hole was regarded as being ready for the running of casing.

15. Summary of drilling procedure. From time to time in this section of the report possible improvements in technique have been suggested, which it is believed may result in savings of time and materials in future deep drilling in the Lisbon field. Before considering the completion of the Vaughn well it may be helpful to summarize these briefly.

Exactly 73 days and 1 hour were consumed from the time drilling actually was begun until the Vaughn well had reached the total depth of 8900 ft. From the time log and other related records the time devoted to various operations connected with the drilling of the well can be segregated and are here listed in Table 18.

It is believed that considerable time may be saved in future deep drilling in the Lisbon field in view of the information herein presented. The saving in time that may be established has been estimated in Table 19.

From the data presented in Table 19 it would appear that it might be possible to deepen a well approximately 3600 ft. below the Pettit lime in about 46½ days from the date of beginning actual drilling operations. Actually this figure is probably too low as some unforeseen delays or difficulties always may be expected. With good equipment and efficient employees, however, it would seem not at all unlikely that a well should be deepened in about 53 days. These figures, of course, do not include time for rigging-up and for original conditioning of the hole, for the running of casing and tubing, for cementing, for completion, and for tearing down the rig. Eliminating these items from consideration, it would reasonably appear that as much as 20 days might be saved in actual drilling time in comparison with the record of the Vaughn well; at a daily rate of $500 this would amount to a saving of $10,000. In addition, as has been previously mentioned, there should be some savings in bits and core cutter-heads in an amount of about $1300.

The question will undoubtedly arise as to whether it might not be less expensive to drill an entirely new hole from the top of the ground to the Lower Marine sands rather than to deepen a Pettit lime well. Some of the operations will be identical, such as rigging-up, coring, electrical surveys, etc. The probable rate of penetration in the deepening of one of the Pettit lime wells now has been established rather definitely, but this cannot be stated for an entirely new hole. It is also obvious that the cost of bits and the rate of penetration will depend on whether 5½-in. or 7-in. casing is set as the long production string. It appears almost certain that the setting and cementing of a protective string of casing in the Pettit lime will be required before a well can be drilled deeper into the Cotton Valley formation. Such being the case the casing program in Table 20 is suggested.

In all probability the larger size hole (Schedule B hole) would cost more than the cost of deepening a Pettit lime well in which 7-in. casing has been set. The large bits and large casing sizes,

TABLE 20

Suggested casing program for Lower Marine Sand wells in the Lisbon field

Casing strings		Weight, lb.	O. D., in.	I. D., in.	Couplings		A.P.I. Grade	Bit through size
Length, ft.	Size in.				Length, in.	I. D., in.		
Schedule A Hole								
900	13⅜	48.00	13.375	12.715	8	14.375	J-55	12¼
5300	9⅝	43.50	9.625	8.755	7¾	10.625	J-55	8⅝
8800	5½	20.00	5.500	4.778	8	6.155	J-55	
Schedule B hole								
900	16	75.00	16.000	15.130	(Slip joint)		J-55	14¾
5300	11¾	60.00	11.750	10.772	10½	12.750	N-80	10⅝
8800	7	26.00	7.000	6.276	9	7.750	N-80	

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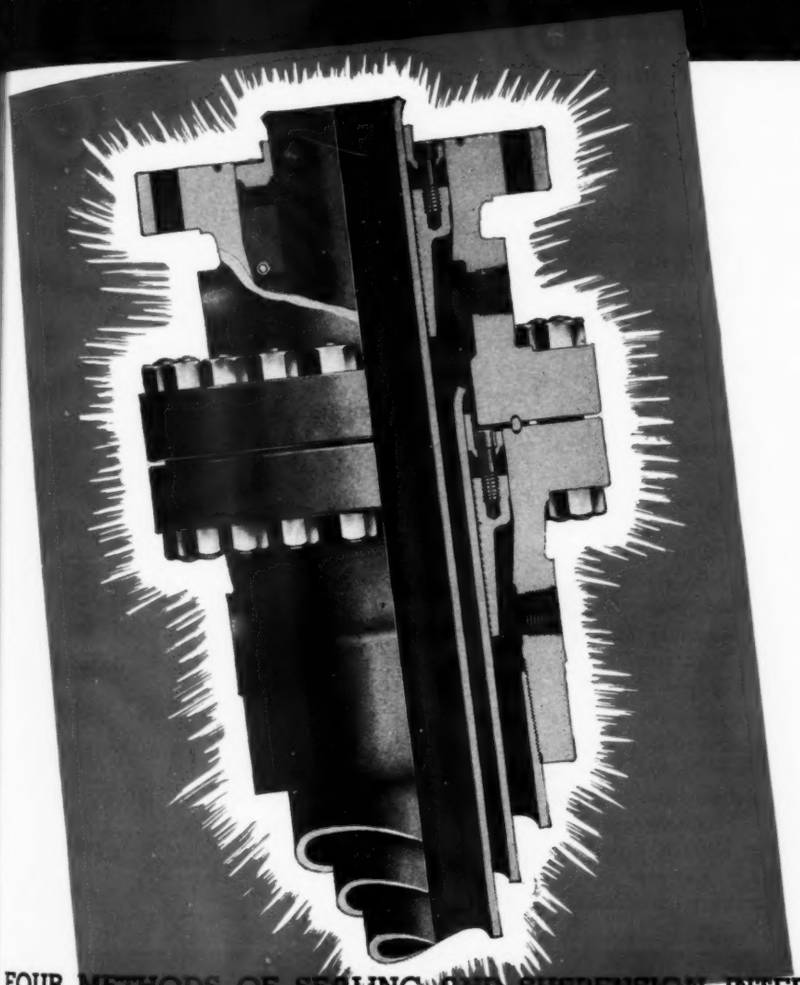

The new low-cost Cameron Type "W" Casing Heads and Spools presented in cross-section herewith round out the Cameron line of well heads.

The Type "W" Casing Head features slip suspension with a neoprene and asbestos seal of the space between the casing strings. As illustrated in the drawing at left, a moulded packing ring and split packing gland are assembled on top of the slips. The packing is compressed by tightening socket head cap screws which screw directly into the top of the slips, thus effecting a pressure-tight seal between the casing strings. Note that there are no threads in the top bore of the housing or spool to be damaged by drilling tools, an objectionable feature of most heads of this general type. Also note that the bolted type gland permits greater gland pressure than is possible with a large screw-type packing gland.

All types of Cameron well heads employ the same casing head housing and spool body, which will accommodate any of the Cameron types of casing suspension. Thus, the operator may install a casing head housing and later select the type of hanger best suited for his particular needs.

Interested operators are invited to write for complete details on all types of Cameron Casing Heads and Spools. An illustrated booklet on the Cameron Closed Pressure Method of Drilling and Completion will also be gladly sent on request.

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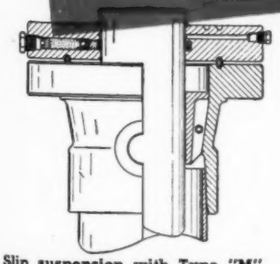
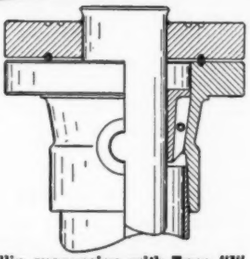
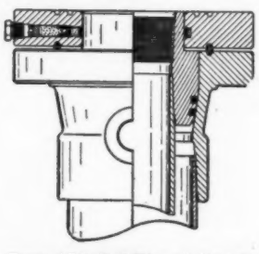


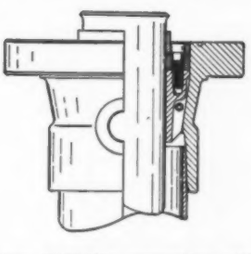
Slip suspension with Type "M" Test-Weld Flange and repackable secondary plastic packing seal.



Slip suspension with Type "J" Welding Flange.



Type "P" Boll-Weevil Hanger with auxiliary repackable plastic packing seal.



Type "W" Slip suspension with neoprene seal.

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TABLE 21

Production string in the Roberta Vaughn No. 1 well (listed from the bottom of the string upward)

Length, ft.	No. of joints	Depth set, ft.	Size, O.D., in.	Description of casing
3716.17	118	5164.55 to 8880.73	5	A.P.I., Range 2, Grade D, 15 lb., 10-thread per in., long threads and couplings: couplings machined from an O.D. of 5.750 in. to 5.375 in.
530.82	12	4633.73 to 5164.55	5	A.P.I., Range 3, Grade J-55, 15 lb., 8-thread per in., long threads and couplings.
4633.73	147	top of kelly bushing to 4633.73	5	A.P.I., Range 2, Grade J-55, 15 lb., 8-thread per in., long threads and couplings.

which would have to be N-80 Grade to provide a proper safety factor, would involve a very considerable expense. It is believed, however, that the cost of a hole in which 5½-in. casing could be set (Schedule A hole) might compare quite favorably with the cost of deepening a Pettit lime well. Obviously the casing cost will be considerably higher in a well drilled from the top of the ground, but in making this comparison the salvage value of the 7-in. casing set in the Pettit lime wells should be considered. It is probable that about the same number of bits would be required for drilling a Schedule A hole as would be required for a deepening operation, but it is believed that the rate of penetration using larger bits and heavier drill pipe might be increased considerably.

The possibility of squeezing the Pettit lime with cement or plugging it with some of the new chemical plugging agents should not be overlooked. It is quite possible one or the other of these methods might be used effectively and thereby eliminate the running of an intermediate string of pipe. If some such method could be applied there is hardly any question but that a new hole would be less expensive than a deepening operation.

COMPLETION

1. Running casing. The hole having been conditioned, as previously described, the running of casing was immediately begun. The casing schedule is given in Table 21.

The length of the float shoe and the float collar was added to the length of the first and second joints in the pipe tally. The total length of the casing from the top of the kelly bushing to the bottom of the float shoe was 8880.72 ft. Allowing for 44 in. of elastic stretch, the bottom of the float shoe was 8884.39 ft. below the top of the kelly bushing. The top of the kelly bushing was used as a depth reference point as all other depth measurements had been taken from it.

A wash-down whirler float shoe was welded on the bottom of the first joint run in the hole, and a float collar was set between the second and third joints from the bottom of the string. Running of the casing was begun at 1:00 A.M. and completed at 6:00 P.M. the same day. When 3716 ft. of pipe had been run into the hole the mud pumps were connected to the top joint at that point and all gas-cut mud circulated from the hole. At the same time the elevating cable was restrung from 6 to 8 lines. Running of the casing was then continued until the bottom of the float shoe was about 15½ ft. from the bottom of the hole.

The pipe tended to stick when being run by the Lower Marine sands, due to the continued formation of filter cake at their face. Elevating and lowering the pipe freed it each time it tended to stick, and it was not necessary at any time to establish circulation around the outside of the casing in order to get the pipe to the desired depth. The new A.P.I. threads on the J-55 grade of casing run in the upper part of the hole turned up with much greater ease than the old style threads on the Grade D pipe that was run in the lower part of the hole.

It is reported that the landing of the casing in the Vaughn well at the desired depth represents one of the longest strings of pipe with the smallest clearance that has ever been run successfully. The clearance between the turned-down couplings and the wall of the open hole was 7/8 in. or 7/16 in. on each side. There was some question, before the casing was run, as to whether external-flush-joint casing might not have gone into the hole with less risk of sticking. This may possibly be the case, but it can be stated that the conventional type of casing with long threads and couplings went to the desired point in the hole uneventfully and with a minimum of trouble. After the pipe was landed at the desired point the two mud pumps were compounded and circulation established through the casing and up around the outside. Circulation was maintained for 25 minutes, and from the size of the

TABLE 22

Cementing record

Started mixing slurry at 7:10 P.M.
Completed mixing slurry at 7:30 P.M.
Time required to mix—20 minutes.
Started pumping plug at 7:34 P.M.
Plug hit float collar at 7:59 P.M.
Time required to pump plug—25 minutes.
Initial pumping pressure—1200 lb. per sq. in.
Final pumping pressure—2000 lb. per sq. in.
Average slurry weight—15.8 lb. per gal.
350 sacks of cement used.

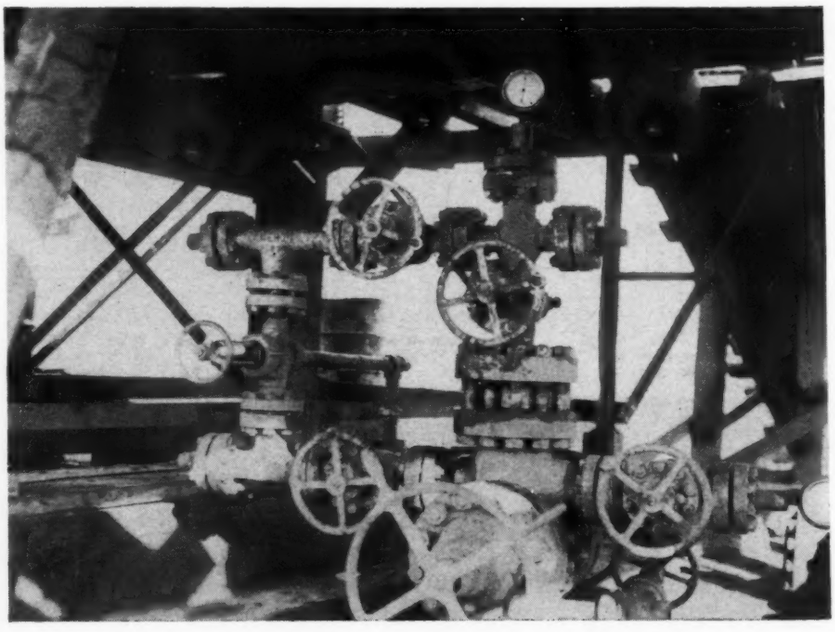

Fig. 9. Casinghead assembly on Roberta Vaughn No. 1 well

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cuttings that came over the shale shaker it appeared that the couplings may have acted somewhat as knives and actually helped in lowering the pipe by cutting their way along the wall of the hole.

2. Cementing casing. While circulation was being maintained around the casing, preparations were being made for mixing and pumping the cement slurry. As soon as mud circulation was discontinued the final connections were made with the cementing truck and the mixing of slurry immediately begun. The record of the mixing and pumping of the slurry is given in Table 22.

The cement used was uniform in consistency and free from lumps. No difficulty whatsoever was experienced in mixing. After the plug was pumped down to the float collar all connections were closed while a pressure of 2000 lb. per sq. in. existed on the casing.

After closing all connections the well was shut down for 96 hr. to permit the cement to set. While the well was shut in, the 3-in. drill pipe was laid-down. On the fourth day, after the casing had been cemented, the pressure was relieved on the pipe, the landing joint removed, and a 10,000-lb. test Christmas tree installed in the cellar. (Fig. 9.) The following day the casing was tested successfully for water shut-off, employing pressure of 2500 lb. per sq. in. The test was approved by the Louisiana Department of Conservation. The cement plug was then drilled using a 4¼-in. rock bit and 2-in. external upset tubing as drill pipe. The top of the cement was encountered at a depth of 8808 ft. and the top of the float shoe, according to tubing measurements, at 8878 ft. This depth corresponded exactly with the depth measurement made on the casing. The cement plug drilled very hard indicating proper curing. After the plug was drilled the mud was conditioned in preparation for perforating the casing.

3. Testing the Lower Marine sands. It will be recalled that four separate sands were encountered in the Cotton Valley formation. These were listed in Table 7 and described in considerable detail in Table 11. A good idea of their possible productivity had been obtained from the electrical surveys, from the record of the gas detector, and from core analyses, but inasmuch as it was desired to obtain all possible information concerning them it was decided to perforate the casing opposite each horizon and test it separately. Originally it was planned to test the Second and Third Sands, then the Vaughn Sand, and the First Sand, in the order listed. It developed, however, that 2⅞-in. drill pipe with external flush joints, necessary to obtain adequate clearance within the 5-in. casing, could not be obtained immediately, and there was some question whether the 2-in. external-upset-joint tubing would be strong enough to pull both a lower and upper testing packer, in order that a separate test could be made on each horizon. It was decided, therefore, that as the blowout preventer on the lower part of the Christmas tree could be closed at any time, thereby eliminating any possibility of a blowout through the casing, it would be safe to test the sands below the First Sand in successive order. Furthermore, as little hope of commercial production was held for the First Sand, it was planned to squeeze it off immediately if it showed salt water before perforating in the Vaughn Sand or the Second and Third Sands. This procedure, as will be shown later, was somewhat altered as the testing progressed.

a. Testing the First Sand. The casing beside the First Sand was perforated with 116 bullets between depths 8354 and 8383 ft. A formation-testing packer was run in the hole on the end of the tubing string and set at a depth of 8345 ft. Thirty-seven minutes after testing was started, the well began to flow mud and wash water. About an hour after the testing tool was opened the water coming from the well began to taste distinctly brackish, and within another hour the well was flowing a strong stream of salt water and only very little gas. After flowing for several hours the testing packer was pulled from the hole and preparations made to remove an obstruction from inside the casing that had previously caused some difficulty.

A casing mill was run-in on the end of the tubing and an attempt was made to cut out the obstruction without success. The tubing was then pulled and the mill replaced with a rock bit. The bit was rotated at about 100 r.p.m. carrying only a very light weight on the bit; by so doing the obstruction was successfully cut out. The 4¼-in. bit could then be run freely to the bottom of the hole.

After clearing the casing of the obstruction, three squeeze jobs were made, using a cement retainer and circulation joint assembly each time, before a successful water shutoff was obtained.

In the fourth squeeze job the tubing was run-in the hole with a cement retainer made of drillable metal, and a circulation joint assembly on the lower end. The retainer was set at a depth of 8320 ft. Using a Halliburton power-driven unit, a water pressure of 4400 lb. per sq. in. was applied to break-down the formation, and 20 bbl. of fresh water was pumped downward through the tubing at an average pressure of 3900 lb. per sq. in. One hundred sacks of cement having an average slurry weight of 15.8 lb. per gal. was mixed and pumped downward through the tubing. The initial slurry pumping pressure was 2300 lb. per sq. in.; after pumping for 20 min. the pressure had increased to 4000 lb. per sq. in. Then for a period of about 5 min. the pressure fluctuated between 3800 and 4500 lb. per sq. in. Twenty-six minutes after the pumping of slurry was begun the pressure had increased to 4700 lb. per sq. in., and in 28 min., when the pressure had increased to 5000 lb. per sq. in., the engine driving the pump stalled, although connected through the lowest possible gear. Including the weight of 100 sacks of cement in the tubing and a pump pressure of 5000 lb. per sq. in., it is estimated that a pressure of at least 10,000 lb. per sq. in. was applied to the perforated section. The cement retainer held tightly even under this severe pressure. The pressure differential of the squeeze job gave a favorable indication of a complete water shut-off. It was estimated that 50 sacks of cement was pumped through the retainer and 50 sacks washed out through the circulation joint. It is fortunate that an ample supply of cement was available as the pressure fluctuation while the slurry was being pumped indicated that the formation was still breaking down while the cement was going through the retainer. The tubing was disconnected from the cement retainer, pulled from the hole, and the well then shut-down for 72 hr. waiting on the cement to set.

After standing for 3 days the cement retainer and cement plug were drilled-out and the well swabbed for 10 hr. The water level was lowered to a depth of 5000 ft. from the top of the hole. The well was then shut-down for 6 hr.; the water did not rise in the tubing, indicating that a complete shut-off had been obtained. This was substantiated in later operations on the well. As the mud was badly contaminated with drilled-up cement and salt water the hole was washed thoroughly with fresh water, the pits emptied of all old mud, and then filled with freshly mixed mud before testing was begun on the Second and Third Sands.

EDITOR'S NOTE: This article will be continued in an early issue.

P 772.441
P 629.2

New Dehydration-Refrigeration Plants Involve Use of Diethylene Glycol

Absorption of water by the glycol in combination with refrigeration by propane results in a gas having a dew point of plus 4° at 1800-lb. pressure

By H. LEE FLOOD
Associate Editor

ONE of the most interesting applications of diethylene glycol as a means of reducing the water content of natural gas has just been made in the K.M.A. field, near Wichita Falls, Texas. Installation of the equipment in which the water extraction is accomplished has just been completed by Continental Oil Company in the three gasoline plants owned by the company and operated in connection with the coöperative repressuring project in which more than 300 operators participate.

The equipment installed at the three plants is similar except that at the main plant, additional chilling is obtained by exchange with excess reflux from the stabilizer. This step in the process is eliminated at the two auxiliary plants because all stabilization is centralized at the main plant and thus no reflux is available except there. Raw gasoline from the two plants is pumped to the main plant for stabilization.

Prior to installation of the diethylene glycol process, gas compressed for return underground was continually causing freeze-ups and stoppages that seriously interfered with the routine of the repressuring project. The primary purpose of the new equipment is to extract water from the gas by absorption, using diethylene glycol as the absorptive medium.

Diethylene glycol is similar in appearance to the better known glycerin or glycerol and to ethylene glycol or glycol, the anti-freeze marketed as Eveready Prestone, inasmuch as all three are colorless, more or less viscous liquids. The properties of the three liquids are listed in the accompanying table.

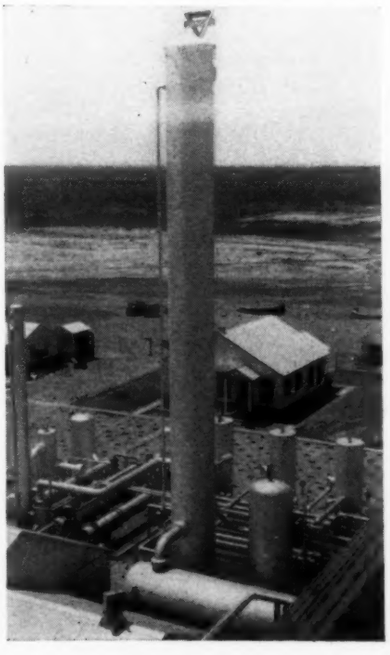
Diethylene glycol has been employed elsewhere for the purpose of dehydrating gas but it is believed that the three installations in the K.M.A. field represent the first instances in which refrigeration has been combined with the process of contacting the gas with diethylene glycol for the purpose of removing water. The advantages of combining the methods are twofold: (1) the efficiency of the glycol as an absorptive medium is increased materially by operating at a lower temperature and (2) the gasoline yield is, of course, increased.

The essential features of the process are presented graphically in the accompanying flow sheet. Although only the equipment involved in the new additions to the plants is shown, it may clarify its use and purpose to describe the manner in which it ties into and augments the equipment previously installed.

The basic plants are combination gasoline-pressure maintenance plants, employing 3-stage compression to recover gas from the wells, extract the gasoline content by the so-called compression method, and further compress the gas to the pressure required for injection underground. Briefly, then, gas is gathered from the wells under a vacuum, is stripped of gasoline, and then is returned below-ground at a pressure of about 1800 lb. per sq. in.

The gas from the gathering system is first received in a vacuum scrubber, then is metered, and subjected to the first stage of compression, in which the gas pressure is increased to 40 lb. per sq. in. from a vacuum not exceeding 10 in. Hg.

New 66-ft. stabilizer column at plant



Following the first stage of compression, the gas is cooled in the cooling tower, which is considered as the initial step in treating the gas, as indicated on the flow sheet. The gas at 40-lb. pressure then enters a separator in which any water formed may be accumulated and drawn-off before the gas enters the second-stage compressors in which the pressure is increased from 40 to 300 lb.

The 300-lb. gas is then cooled in coils under the cooling tower and enters the water separator in which a considerable portion of the water drops out and is drawn-off. Gasoline condensing in this vessel is also removed; separation of the streams of the two liquids, gasoline and water, is automatically controlled by a dual-gravity level controller. The gasoline thus recovered is then re-introduced into the gas stream.

The gas stream leaving the water separator at a temperature of about 90°F. is then contacted with diethylene glycol by injecting the chemical into the gas stream at a rate of about 3 g.p.m. The stream of gas-glycol mixture is then given an initial chilling in a series of three heat exchangers utilizing the low-temperature residue gas obtained overhead in the high-pressure (300 lb.) gasoline separator. From the exchangers the residue gas enters the high-stage compressors and is then returned to the field at a pressure of 1800 lb. per sq. in.

The stream of gas-glycol mixture leaving the exchangers at a temperature of about 40°F. is then split, the greater portion going directly to the propane chillers. A smaller volume of the mixture is routed through heat exchangers countercurrently with the gasoline stream from each of the separators operating at 300, 135, and 70 lb. per sq. in., respectively, as shown. The three streams of gas-glycol mixture from these exchangers then reenter the main stream of mixture and pass to the propane chiller. Thus, the entire stream of gas-glycol mixture is subjected to cooling in the propane chiller (and, at the main plant only, in the chiller using excess reflux gas);

the volume diverted from the main stream merely passes through the exchangers as described and then re-joins the main stream.

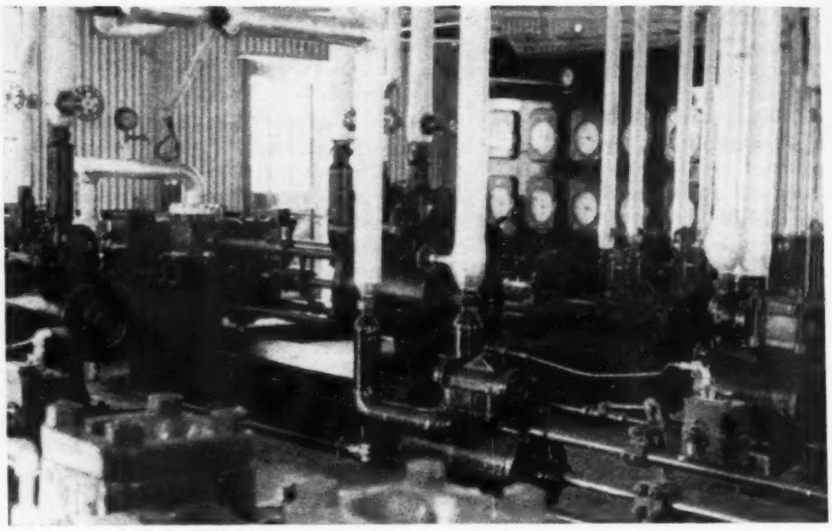
After the gas has been chilled, it then enters the high-pressure or main gasoline separator, on which the intermediate pressure of 300 lb. is maintained. Entering this vessel at low temperature and high pressure, all the gasoline extracted in the plant is "dropped out" at this point in the cycle. Subsequent separations at successively lower pressures merely "refine" the product by eliminating the more volatile constituents, reducing the load on the stabilizer column.

Thus, gasoline leaving the main separator, after passing through a heat exchanger, is introduced into the first of three vent separators. Operated at 135 lb., 70 lb., and 50 lb., respectively, these vessels permit the gaseous fractions to come out of solution, resulting in a more stable gasoline following each pressure reduction.

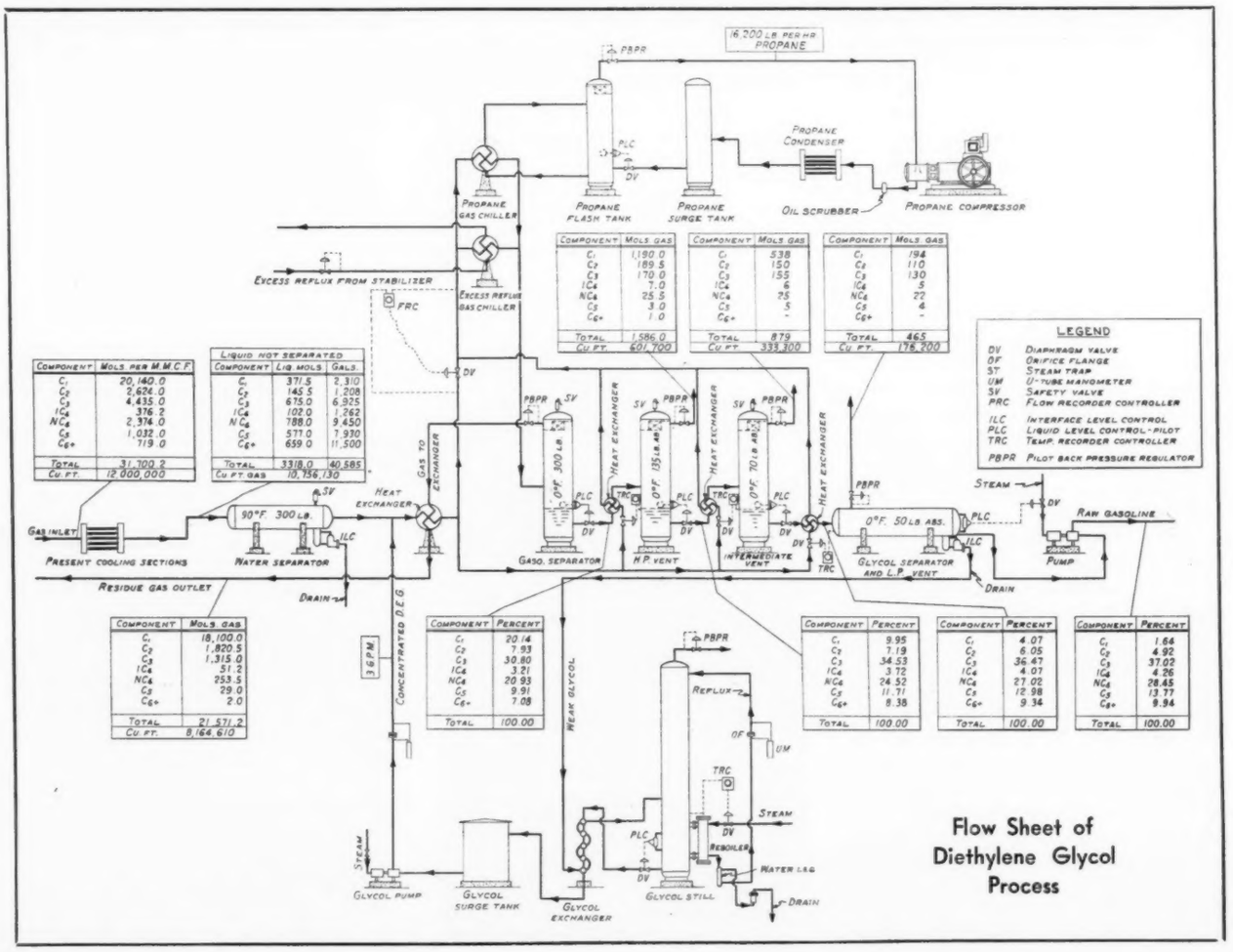
The gases from the three vent separators are piped to the plant flare, inasmuch as the volumes are not large enough to warrant recompressing. In review, it will be recalled that the gas from the main separator is used to im-

Physical Properties of Anti-Freeze Chemicals

	Glycerin or glycerol	*Ethylene glycol or glycol*	*Diethylene glycol*
Formula	$CH_2OHCHOHCH_2OH$	CH_2OHCH_2OH	$O(CH_2CH_2OH)_2$
Molecular weight	92.06	62.05	106.08
Melting Point, °C.	17.9	—17.4	—10.45
Boiling point, °C.	220.	197.2	244.5



Interior of pump room



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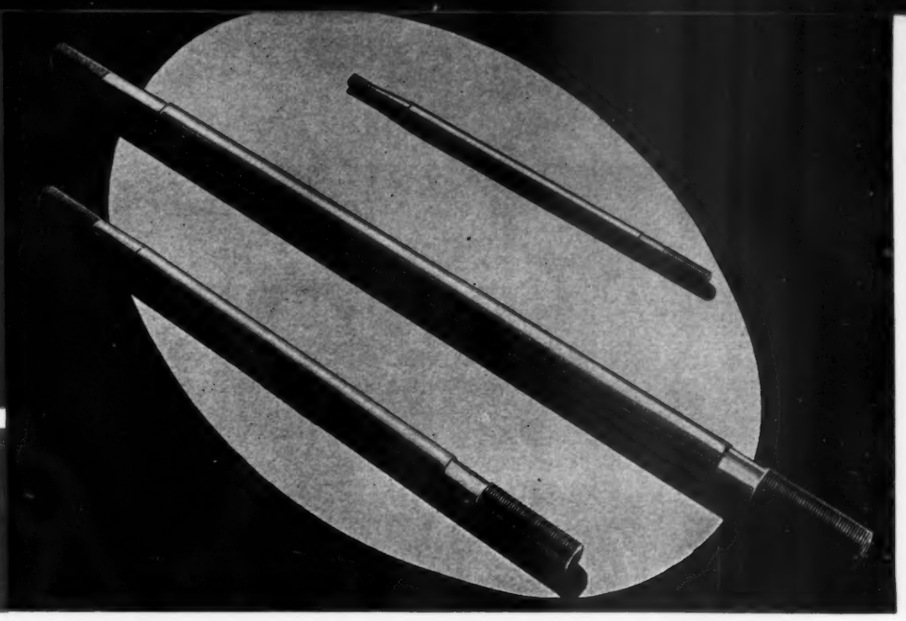

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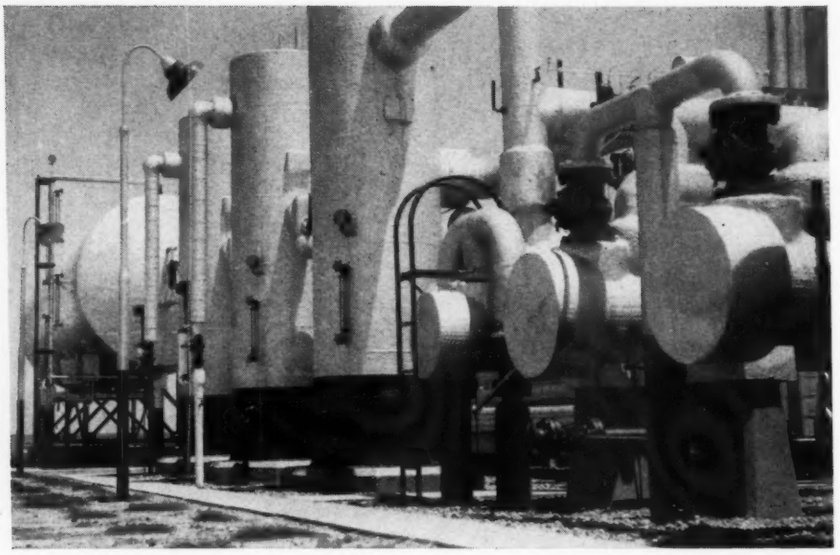


Primary cooling exchangers in foreground; the three vertical vessels are gasoline separators and elevated horizontal tank in background is the glycol separator

part the initial chill to the incoming gas-glycol mixture and is then compressed to 1800-lb. pressure and returned to the field.

At this point, it is perhaps well to mention that the absorption of water by the diethylene glycol occurs continuously throughout the chilling and gasoline extraction processes. The glycol, becoming increasingly more diluted, drops out, of course, in the separators.

After passing through the final bank of heat exchangers following the separation at 70-lb. pressure, the gasoline-dilute glycol mixture enters the glycol separator. The latter vessel is a large (25,000 gal.) horizontal tank in one end of which a steel plate serves as a weir, the notch of which is cut to maintain the liquid level about 12 in. from the top of the tank. Enough capacity is provided in this tank to permit ample time for the gasoline and glycol to effect a complete separation by gravity.

The gasoline from the glycol separator is pumped to the raw gasoline storage tank and is mixed with the raw gasoline pumped from the two auxiliary gasoline plants situated elsewhere in the field. Thus the total volume of gasoline produced by the three plants is concentrated at the main plant and is then stabilized, usually to a 26-lb. product, and is then pumped to a loading rack several miles north of the plant. A pipe line now being constructed will serve as a more direct outlet to Continental's Wichita Falls refinery.

The weak glycol liquor is reconcentrated in a glycol still, using steam as a heating medium and water as reflux. When concentrated, the glycol enters a surge tank, to be picked-up and pumped into the rich gas stream.

The propane cycle in the process is more or less conventional. Propane compressors pick-up the gas leaving the chillers and compress it to about 180 lb. The propane at this pressure enters the flash chamber in which a reduction in temperature is attained by reducing the pressure to about 10 lb. The cold gas then cools the gas-glycol mixture and is returned to the compressors. At the present time the total compressor capacity assigned to this service is being augmented by the installation of two 230-hp. compressors.

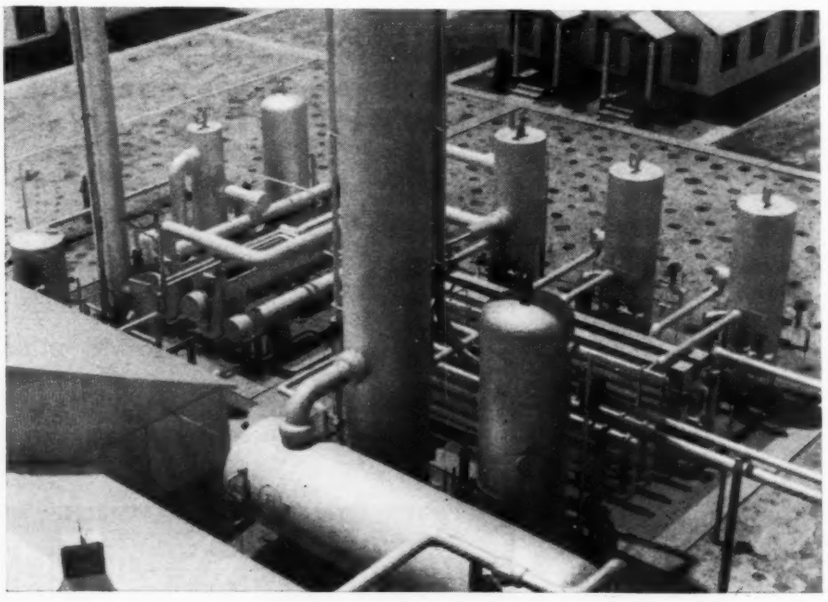
Each of the three plants has a throughput capacity of 12,000,000 cu. ft. per day. Depending entirely upon the combination of requirements varying from time to time in the field, as well as in the plant, the gasoline produced may approximate 40,000 to 50,000 gal. per day, more, possibly, under ideal conditions.

In operation only a short time, the new equipment is performing in accord with expectations. At the present time, a hydrocarbon dew point of minus 17°F. and a water dew point of about minus 24°F. are being attained; both at 300 lb. When compressed to 1800 lb., the gas has a dew point of plus 40°F., a satisfactory condition for hydrate-free operation during the greater part of the year. To eliminate positively all possibility of freeze-ups during the winter months, it is believed that a dew point of less than zero should be obtained. It is for this purpose that additional compressor capacity is being installed.

An important part of any plant is the pump room. In connection with the new equipment and serving the prior installation as well, there are nine reciprocating pumps and four centrifugal pumps driven by two steam turbines housed in a well-planned pump room centrally situated in the plant.

Two of the three 8 by 10 by 20 pumps serve to pump reflux and raw feed, respectively, and the third serves as a standby.

Two 6 by 1½ by 10 pumps deliver glycol into the gas stream; one 6½ by 6 by 12 pump serves as a transfer pump; a 10 by 4½ by 12 pump is used as a loading pump, delivering gasoline to the loading rack; a 10 by 7 by 18 pump is a standby for the loading pump, and a 6 by 6 by 12 pump serves as a utility pump.



General view of equipment

P 451.
P 511.7

Removal of Drilling Mud from Formation by Use of Acid

New chemical treatment removes silicates from drilling mud—accelerates bringing-in of wells previously difficult to swab-in

By STANLEY C. MORIAN
District Engineer, Dowell Incorporated

THE USE of mud is a necessary part of drilling wells in the Gulf Coast area but the mud sheaths, filter cakes, and rotary fluid penetration into the sand often retard and sometimes completely stop production.

A new method of eliminating this difficulty has resulted from the development of a mud acid that actually dissolves the mud. This is quite different from acidizing as practiced in lime-producing areas and necessarily must be considered as an important forward step in production engineering.

Some of the advantages of a mud-free producing section from the viewpoint of the economies of operations and increased ultimate recovery are, briefly, as follows:

1. Reduced time for the well completion step—less rig time
2. Longer-lived well and longer flowing life
3. Less emulsion troubles and no prolonged slugging of mud and water
4. True picture of well's potential and pressure
5. Less chance of passing up a commercial producing section
6. More successful work-over jobs, especially in old wells.

Table 1 gives a number of case histories covering the successful application of mud acid in the treatment of Gulf Coast wells.

Electrical logging indicates that the mud cake may extend from the face of the producing formation back several inches into the sand, and the water squeezed-out of the mud may lie dormant beyond this wall of mud. This further tends to obstruct the flow of the less viscous gas and oil through the "critical zone of flow" or first few inches of formation away from the well bore. The problem of demudding the well, therefore, would appear difficult in that the mud must be removed not only from the face of the formation, but from the pores of the formation near the well bore, and the water removed from behind the wall of mud.

Research and development work have been in progress in an effort to design a method to demud sand formations. Such materials as commercial hydrochloric acid, various mud thinners and conditioners, mechanical washers, as well as acid-soluble mud have been used in an effort to expedite the completion process and provide a clean bottom-hole condition. Of these, only acid-soluble mud proved practical on any large scale.

STANLEY C. MORIAN

was born in Bradford, Pennsylvania —Received degree in petroleum engineering at University of Oklahoma in 1934—1934-1937, worked in drilling and production in Western Kansas, New Mexico, West Texas, and Oklahoma — Joined Dowell Incorporated, in March, 1937, as district engineer in West Texas—Came to Gulf Coast for the company early in 1938.

As not all operators in Gulf Coast areas use lime or acid-soluble mud, the problem of demudding was then attacked from another angle. This involved the development of a specific solvent and treatment for the usual type of drilling mud used in the Gulf Coast area. After a lengthy period of field applications, conclusions were reached regarding the formula, volume, and technique of the application of the mud acid to be used, and these conclusions are outlined here.

When acid-soluble mud is used, inhibited hydrochloric acid is capable of providing complete removal but the new mud acid may be used in any well, regardless of the type of mud used. This new mud acid has several desirable properties:

(a) It is capable of dissolving not only limestone and dolomite but it also will dissolve silicates used in mud
(b) It is non-corrosive to well equipment
(c) It has a surface tension as low as that of oil
(d) It has excellent penetrating properties.

Ordinary inhibited hydrochloric acid used in the treatment of oil wells will dissolve dolomite and limestone encountered in most formations but it will not rapidly dissolve the type of silicate compounds in most drilling muds. The new mud acid is very reactive to carbonates and silicates, but is non-reactive on iron and most other metals used in oil-well equipment. The surface tension of this special mud acid is as low as that of oil, thus permitting it to penetrate easily the oil-soaked mud cakes of the formation. The mud acid also possesses very good detergent or washing qualities such as are found in normal soap solutions and, by its dispersing properties, acts to remove from the formation immediately surrounding the well bore, the insoluble residues previously held in suspension. The advantages of mud acid, as compared with raw acid, are shown by the two curves in Fig. 1.

Some laboratory studies of the typical muds used in the drilling of Gulf Coast wells were made in an effort to compare the value of ordinary hydrochloric acid with the newly developed mud acid. Samples of mud were collected as shown in Table 2.

In order to study the mud removal effect of ordinary inhibited acid as compared with the new mud acid, strips of wire screen ¾ in. by 2½ in. were plastered with the mud and then attached to the apparatus shown in Fig. 2. In this test, the screens with their mud sheaths were allowed to move up and down in the various solv-

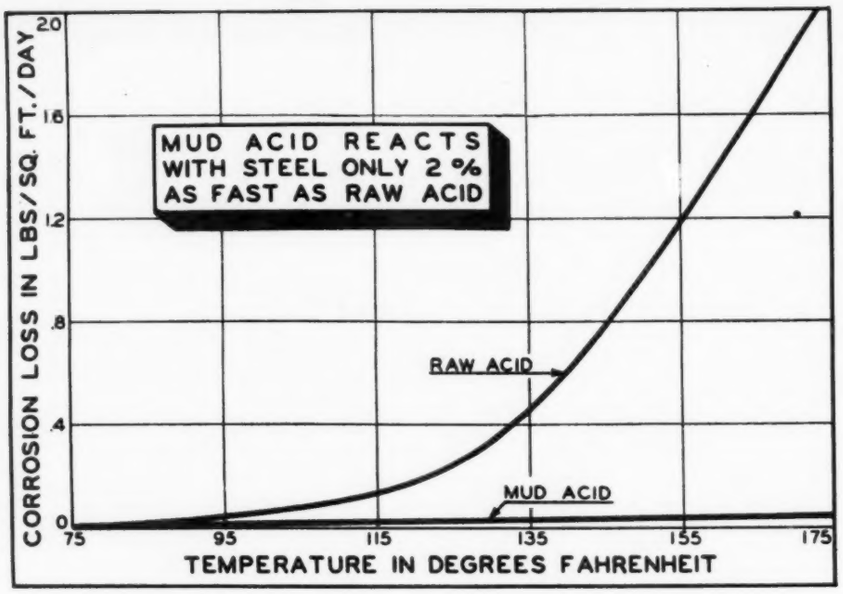


Fig. 1. Comparative action of mud acid and raw acid

ents. The data in Table 3 are the results of this study. It is interesting to note that the ordinary inhibited acid did not dissolve the mud but caused it to slough off the screen into the bottom of the test tubes. By way of comparison, the mud acid not only cleaned the screens in a shorter time, but also dissolved the mud.

In the Golden Meadows field of La Fourche Parish, Louisiana, some difficulty has been experienced in bringing-in wells following rotary completion. It was thought that possibly the sand had been mudded-off and some indication of this was observed by an analysis of the formation. Table 4 contains an X-ray analysis of a core section from one of the Golden Meadow wells and shows that there is definite evidence of mud penetration into the formation.

Separate samples of some of the sand from the abovementioned well were refluxed, dried, and treated with ordinary inhibited acid and with the new mud acid. The results of this investigation are shown in Table 5.

Another portion of this sand was treated in stages with mud acid and it was found that stage-treating resulted in greater solubility, as shown in Table 6.

Cores from a well in another Gulf Coast field, which were impregnated with drilling mud during the coring process, were analyzed for water content, solubility in ordinary 15 percent hydrochloric acid, and solubility in the new mud acid. These data are shown in Table 7.

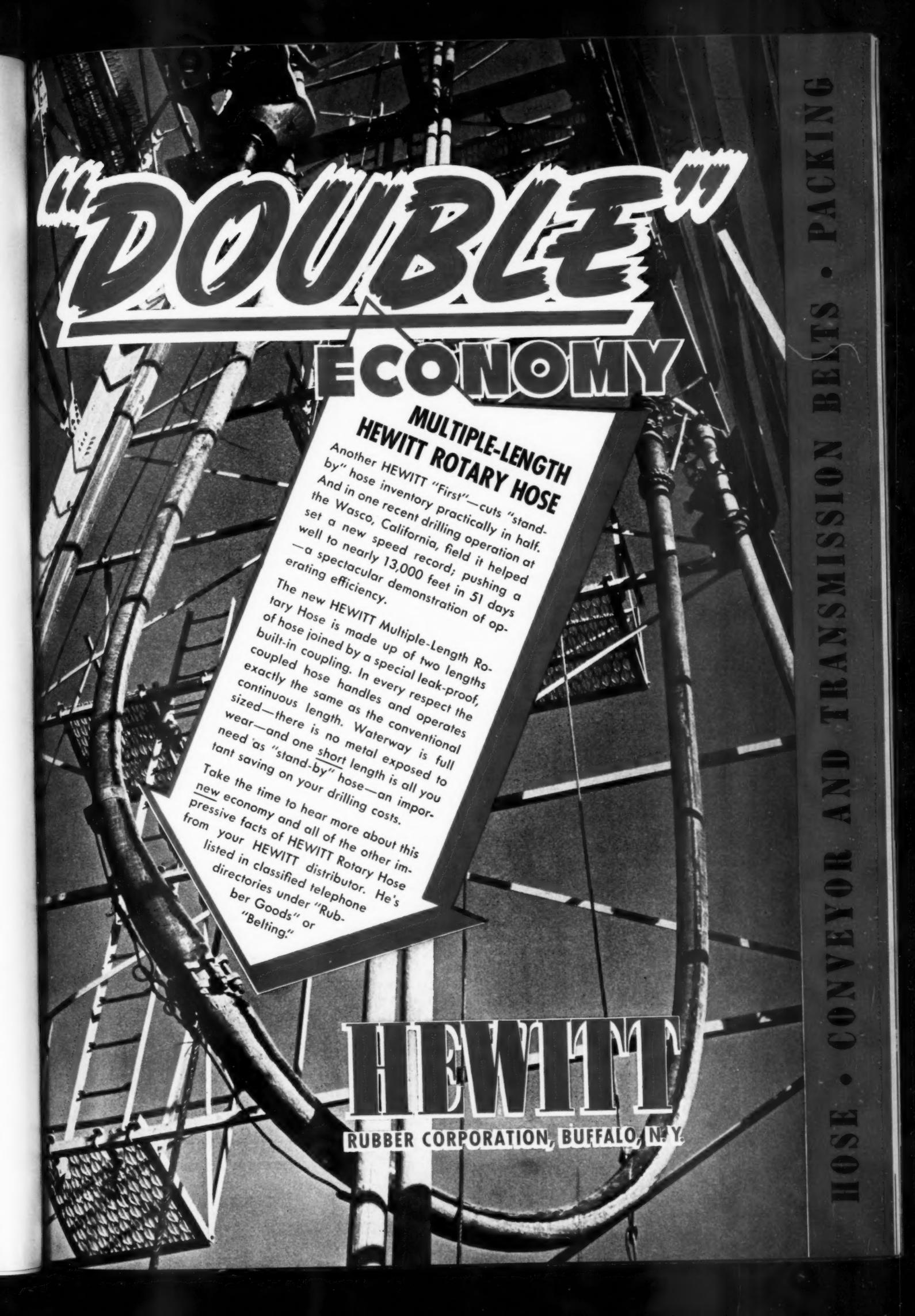
Treating Technique

Methods of treating were developed entirely in the field and are the result of closely observed well behavior during and after treatment. The proper quantity of mud acid to be used is dependent upon the amount of sand section exposed. The most satisfactory results have been obtained by using 1000 gal. of acid for each 10 or 15 ft. of exposed pay section. Half of the total volume may be mud acid and the balance composed of a wash solution.

TABLE I

Typical results of demudding treatments

Well No.	*Purpose of well treatment*	*Gal. mud acid used*	*Maximum treating pressure, lb. per sq. in.*	*Results*
1.	To demud well. Well had been killed with 14-lb. mud to set screen. No flow after setting screen, washing, and swabbing.	1000	2400	Well kicked-off and flowed 150 bbl. per day immediately after treatment.
2.	Well drilled in 1933; worked-over in 1934, and "lost" due to mudding-off pay zone. Several months spent in effort to recover. In 1940, cleaned-out and demudded with mud acid.	1250	1100	Prior to treatment and during clean-out, well swabbed about 8 bbl. per day for 7 days. After treatment well flowed 130 bbl. per day consistently.
3.	From 5 to 20 days are required normally to "wash in" wells in this pool after setting screen. Treated well with mud acid as soon as screen was set.	1250	850	Well started to flow few minutes after treatment. Was making "pipe-line" oil 12 hr. after treatment.
4.	Old well being worked over. Mudded-off while setting screen inside old screen.	1500	500	Before treatment swabbed 8 bbl. per day. After treatment pumped 55 bbl. per day.
5.	Work-over job left producing formation mudded-off. Operator had spent 3 weeks trying to wash well back in—then used mud acid treatment.	1000	525	Few hours after treatment well came back flowing pipe-line oil.
6.	Treated to demud and clean sand face. New well completed in shaly sand for 32 bbl. per day.	1000	1750	Well made 110 bbl. per day after demudding treatment.
7.	Treated to demud and clean gun perforations. Old well. Had never been as good as offsets. Declined to 10 bbl. per day due to mud left in the sand.	1000	2300	Immediately responded—flowing 250 bbl. per day.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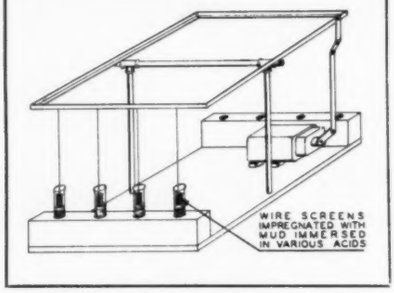


Fig. 2. Test apparatus

TABLE 2

Mud sample	*Location*	*Depth, ft.*	*Remarks*
1	Eola pool—Avoyelles Parish, La.	8460	In green shale above Wilcox
2	Hackberry pool—Cameron Parish, La.	3360	Low-pressure sand—10-lb. mud
3	Ville Platte pool—Evangeline Parish, La.	8825	Coring for Wilcox
4	Cheneyville pool—Rapides Parish, La.	5558	Coring for Cockfield—formation mud
5	Golden Meadows pool—La Fourche Parish, La.	2553	Coring—water and formation mud
6	Quarantine Bay pool—Plaquemine Parish, La.	.....	Sample from mud trough

TABLE 4

Quartz (SiO_2)—60-70 percent

*Beidellite (clay)—20-30 percent

Feldspar (albite-anorthite series)—10 percent

*(Beidellite belongs to the same general group of clay minerals as montmorillonite, kaolinite and ceutonite, which exhibits swelling characteristics in water, due to the water molecules entering between the sheets of linked silicon-oxygen tetrahedra and breaking the relatively weak hydroxyl bonds normally holding these sheets together.)

TABLE 3

Time required for removal of moist mud sheath from screen

Sample No.	*Depth, ft.*	*15% ordinary inhibited acid*	*Mud acid*	*After drying screen for 2 hr. 15% ordinary inhibited acid*	*Mud acid*
1	8460	90% in 25 min.	100% in 4 min.	45 min.	14 min.
2	3360	100% in 4 min.	100% in 4 min.	40 min.	13 min.
3	8825	90% in 25 min.	100% in 3½ min.	60 min.	30 min.
4	5558	75% in 25 min.	100% in 2½ min.	50 min.	13 min.
5	2553	75% in 25 min.	100% in 4 min.	48 min.	12 min.
6	.....	90% in 40 min.	100% in 5 min.	40 min.	2 min.

TABLE 5

	Percent soluble	*Residues by X-ray analysis*
Ordinary inhibited acid	3.3	20-30% Beidellite
Mud acid	20.03	10-15% Beidellite

TABLE 6

Stage	*Time*	*Percent soluble*
1	15 min.	11.0
2	15 min.	6.2
3	15 min.	5.8
4	15 min.	4.2
	Total solubility	27.2

TABLE 7

Sample No.	*Depth, ft.*	*Percent water*	*Percent soluble in ordinary inhibited acid*	*Percent soluble in mud acid*
1	5355-56	9.2	2.3	33.3
2	5358-59	6.12	1.8	31.9
3	5375-76	12.1	4.4	43.8
4	5388-89	12.3	1.9	23.8

The basic technique followed in new wells may be outlined as follows:

1. With the hole full of mud the screen is placed in position to set the packer and tubing is run to bottom.
2. Five bbl. of chemical wash solution is introduced into the well followed by the mud acid.
3. The first half of the mud acid is circulated slowly over the face of the formation behind the screen. During this operation the casing valve is open.
4. The liner packer is set, the Christmas tree assembled, and the well made ready to bring in.
5. The remaining half of the mud acid is forced into the formation, the acid being displaced from the tubing and open hole by means of a chemical wash solution.
6. Two hours after completion of the treatment the well is ready to be swabbed-in.

In actual practice, the technique may vary from the above procedure, depending upon the condition of the well to be treated, the equipment, and the particular problem involved.

Fig. 3 illustrates the various steps followed in the introduction of mud acid into the well.

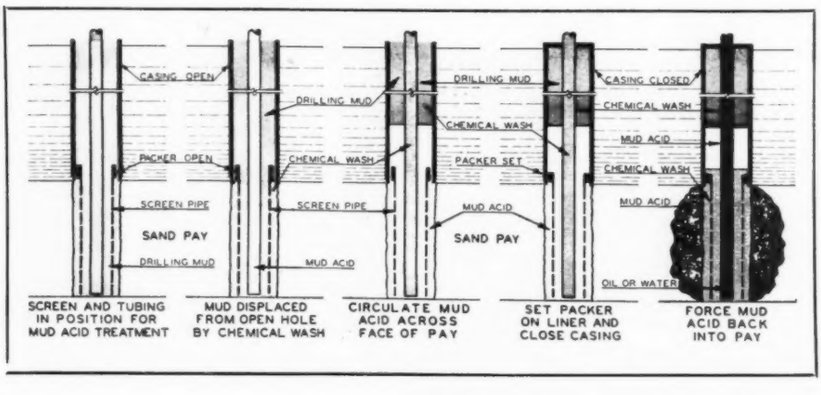


Fig. 3. Steps in introduction of mud acid

P 432.
P 44.31

Drilling and Completion Practices in Illinois Basin Involving Use of Lightweight Alloy Metal

Multiple-zone production has stimulated development of casing sections, float collars, centralizers, guide shoes, and other equipment fabricated of removable metal

By RALPH C. GRAHAM
Security Engineering Company, Inc.

REVIVAL of oil activity in Illinois has served to focus attention on the marked progress made by the industry during the last 30 years. Highly competitive drilling programs with few restrictions on the accompanying production forced oil operators to adopt methods not visualized during the first active drilling campaign of some 30 years previously. The original development of the Illinois Basin was initiated by operators moving westward from Pennsylvania, Ohio, and West Virginia, at a time when cable-tool drilling was the accepted practice. The year 1908 saw the Basin's production at a peak of 33,686,238 bbl. per year, which has been far surpassed during the last two years. Multiple sand completion and production required new methods, for one of the principal characteristics of the pools is the presence of several producing sands. Owing to the prevalence of tightly cemented producing formations, a preference was shown for the use of nitroglycerine shots to produce these sands. Open-hole production of more than one sand was made impracticable by the intervening shale beds, which had a tendency to slough badly and fill the hole. The problem then consisted of finding a method whereby a casing string could be set on top of the lower zone and the upper zones exposed by some method not as yet in common usage in this area. As this fact became recognized, operators initiated the use of alloyed metal sections in the casing string opposite the upper zone. This method was based upon the metal's susceptibility to removal from the hole easily.

These alloyed metals are made in various size tubular goods for oilfield use and have adequate strength to be handled at the rig similarly to steel pipe. Care is exercised in lowering the pipe in the hole, however, because alloy casing cannot withstand the same vertical column load as steel. Possible bridges and tight spots in the hole have to be looked for, as very few holes are drilled with the aid of reamers. It is ideally suited for removal either by the use of a piloted-type five-bladed drag bit or a conventional wall scraper. Rotary table speeds ranging from 50 to 125 r.p.m. and a bit weight of 2000 lb. have proved most satisfactory, the average rate of removal being apparently 5 ft. per hour. This rate of removal has been influenced by the presence of cement behind the removable section, for the metal cannot be removed any faster than the cement itself. Mud screens or some other adequate method must be used for removing the cuttings from the mud returns to prevent recirculation of the cuttings and the possibility of forming bridges in the hole or plugging the pumps, bit, or drill pipe. One typical drillable metal possesses certain mechanical and physical properties suitable for oil-field requirements, as shown at the bottom of page.

RALPH C. GRAHAM

graduated from Missouri School of Mines in 1931, receiving his degree in petroleum engineering—Was first affiliated with The Texas Company in Oklahoma, later employed by The Carter Oil Company in 1934 and engaged in various drilling and producing work in Oklahoma—Transferred to Illinois in 1938 and resigned in 1939 as district engineer to enter the employ of The Security Engineering Company, Inc.—Is now at the Whittier, California, main office.

Reduced Section in the Casing String

The first method employed to produce more than one sand from a common well bore is illustrated in Fig. 1. The installation was made on September 19, 1938, in the Loudon pool by a major oil company in an endeavor to solve the problem of multiple sand production methods. In this particular installation, 33 ft. of 5-in. O.D. drillable casing having an I.D. of 4.29 in. was inserted in the 6-in. O.D., 14.61-lb. steel casing string opposite the upper or Weiler zone approximately 45 ft. above the lower or Benoist zone and cemented in place. A 5-7/16-in. piloted-type five-bladed drag bit was used to remove the reduced metal section and that part of the cement plug left inside the casing opposite the reduced section. This was followed by a wall scraper to remove the cement behind the reduced section and re-expose the sand face. The steel casing below the reduced section was then removed without difficulty and the rest of the cement plug removed. The lower zone

Ultimate strength	38,000 lb. per sq. in. (minimum)
Yield strength	32,000 lb. per sq. in. (minimum)
Shear strength	26,000 lb. per sq. in. (minimum)
Elongation (percent in 2 in.) .	20
Specific gravity	2.69
Weight, lb. per cu. ft. . . .	0.097
Modulus of elasticity . . .	10,300,000

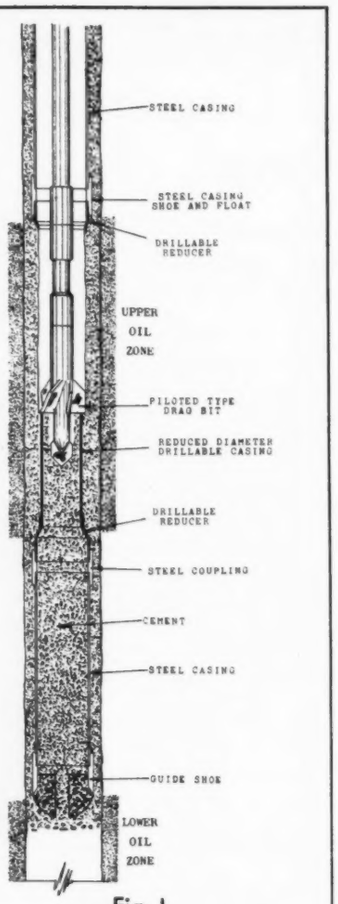


Fig. 1

was then completed and placed on production. Due to interbedded shale zones within the upper sand body the well was never successfully completed as a two-zone well because the shale tended to slough-off in the hole and impede production methods.

From this installation and subsequent removal, however, certain standard practices were developed. It was found that heavy casing shoes should be placed at both ends of the metal section to safeguard the casing during the shooting and to facilitate the movement of the tools in and out of the isolated casing sections during reconditioning or completion work. The reduced section method necessitated leaving considerable cement in the casing and completing the upper zone first, which was undesirable. It also required two runs, the first with a piloted-type drag bit to remove the drillable metal and the second, with the wall scraper, to remove the cement opposite the sand face. This method was then largely discarded in favor of the method shown in Fig. 2 and with the exception of a few operators who use the reduced section so it can be removed with cable tools, is the one most generally used.

Same Dimensional Section as Casing String

The method illustrated in Fig. 2 is now commonly accepted as the most efficient practice. The drillable section, having relatively the same I.D. and O.D. as the steel casing, is inserted in the casing string between two heavy casing shoes opposite the upper horizon. The casing string is cemented throughout its entire length or to a point well above the upper horizon. The casing is set on top of the lower sand, which is completed and tested first. The well is either plugged-back immediately or at some later date to the base of the upper zone and the drillable section removed by means of a wall scraper. The upper zone is then shot with nitroglycerine, tested, and completed. The plug is removed and both zones are produced through a single oil string. The longest section of steel casing hung below a drillable section in the Illinois Basin to date has been 1254 ft., and the greatest number of removable sections placed in one casing string has been four.

Cable-Tool Removal of Reduced Sections

As some operators move rotary tools from the well as soon as the casing is set and then complete the well with cable tools, experimental work has been

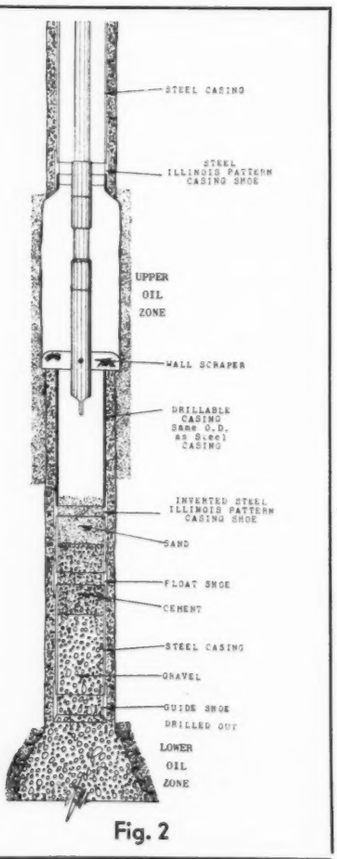


Fig. 2

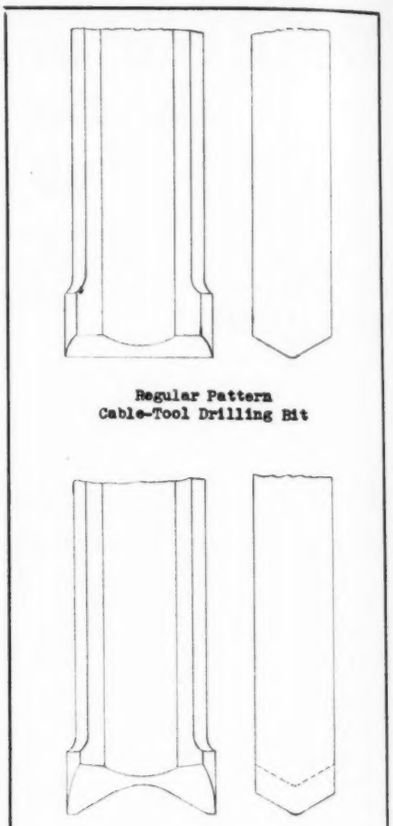
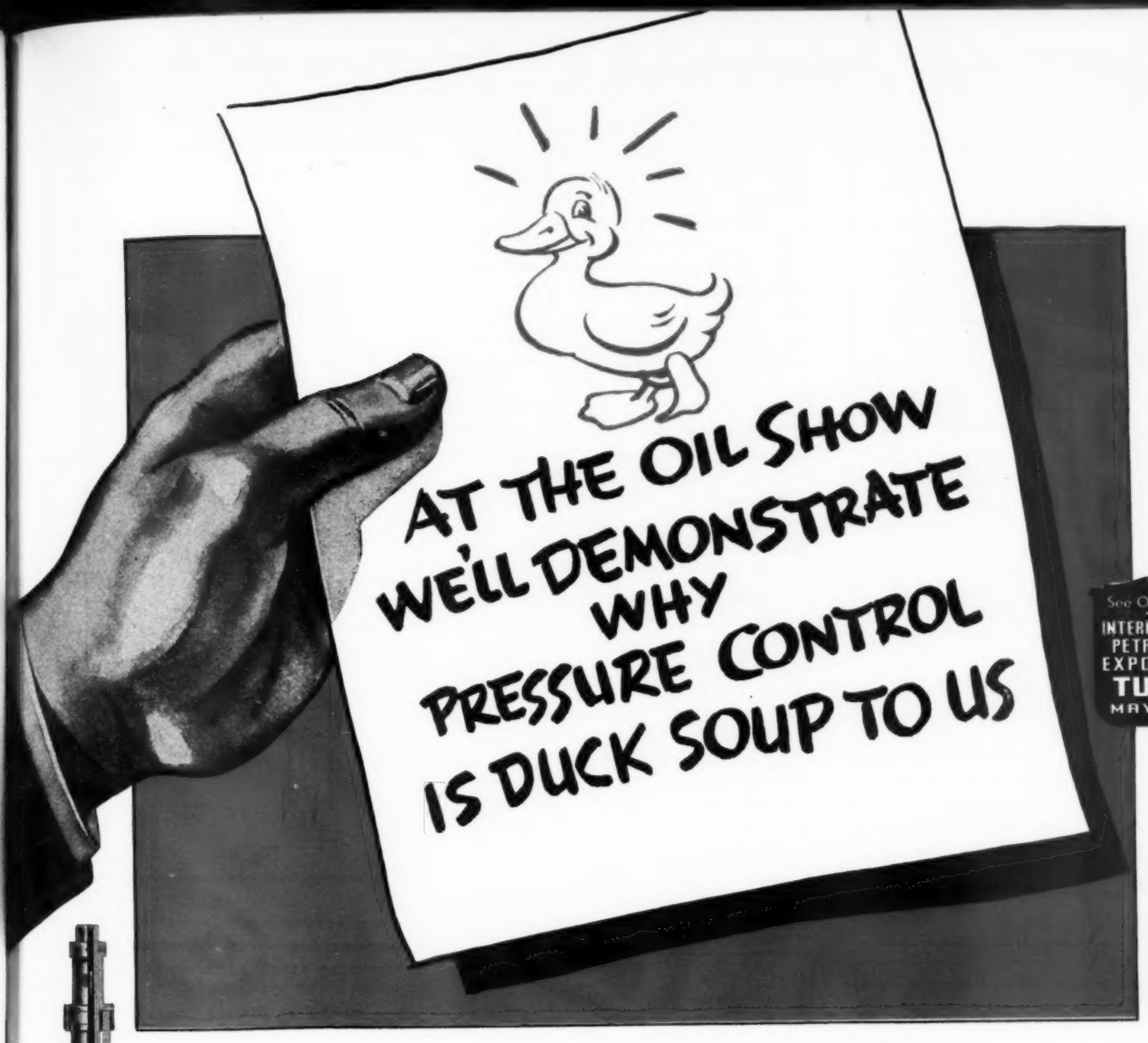


Fig. 3

conducted in methods of removal by cable tools. Fig. 1 is again cited as an illustration of the method of inserting the drillable section in the casing string. This method was used by an operator in the Keensburg pool, employing a casing string of 5½-in. steel casing and 13 ft. of 4½-in. drillable casing inserted opposite the upper producing formation. The reduced section was installed between two heavy casing shoes and reduced by means of drillable swedges. The cement was left in the casing to a point above the reduced section of the drillable metal to provide the cable-tool bit with a solid mass to work upon. The bit was altered in design, as shown in Fig. 3, to enable the bit to direct the section being drilled toward the center rather than to swedge it outwardly. This tended to break off chips of a size that would be readily removable with a bailer. The conventional type cable-tool bit was first employed, but had a tendency to stick in the liner as it swedged it outwardly. Drilling progress with the altered bit design was as rapid as when removing the cement plug; the section was removed at a rate of approximately 2 ft. per hour. This method necessitated completion of the upper



Control, combined with ingenuity, has been the secret of the successful business Otis Pressure Control, Inc., has built in triumphing over the complete range of pressures in producing wells. ● For high pressure wells there is the surface-controlled Otis Removable Bottom Hole Regulator, illustrated at the left, which safely reduces highest tubing flowing pressures and positively eliminates freezing of surface controls. ● For wells where gas pressure is insufficient to produce oil, Otis devised the Type G (Side Door) Otis Removable Bottom Hole Choke, illustrated at the right. It utilizes gas from a surface source or an upper horizon to flow the well at a controlled ratio. We would like to demonstrate both these tools for you at our display (Booths Nos. 224-225) in the Oklahoma Building.

OTHER OTIS *PRESSURE* CONTROL TOOLS ON DISPLAY:

Types B and E Removable Bottom Hole Chokes
Removable Tubing Safety Valve
Types C, E and G Closing Tools
Removable Drill Pipe Float Valve
Automatic and Wire Line Paraffin Scrapers
Complete Line of Running and Pulling Tools for Otis Equipment.

WRITE OR CALL TODAY for additional information about Otis tools if you are not planning to attend the Oil Show.

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DALLAS, TEXAS

Division Offices: **Houston, Texas; Oklahoma City, Oklahoma; Hobbs, New Mexico**
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Representatives: **Otis Eastern Service, Inc., Wellsville, New York**
Western Pressure Control, Inc., Los Angeles, California

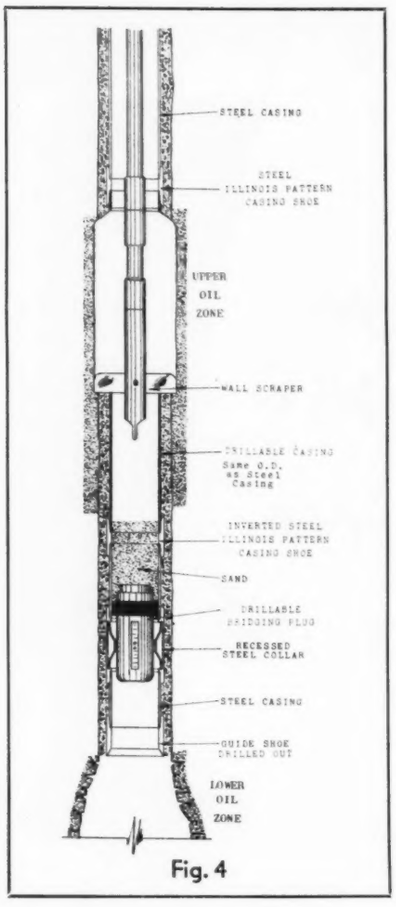


Fig. 4

zone first as the reduced section limits the tools, shot shells, and other equipment to a size not suitable for completing the lower zone first, and for this reason the practice has not been universally accepted.

Along this line, it should be mentioned that some operators, after moving rotary tools from the well, have completed the lower zone with cable tools, plugged-back to the base of the upper sand, and removed the drillable section by means of a nitroglycerine shot. As has been pointed out, it is necessary to shoot the sands to produce them properly, and by this method the operator has been able to eliminate one step in the completion process. No trouble has been reported in removing the metal fragments, and apparently the initial production is as large as by the mechanical method. Only a limited number of wells has been subjected to this method, however, and its use is not common practice at this time.

Drillable Plug for Multiple Zone Completions

In developing the technique of the new completion practice, a drillable plug was introduced for plugging-back from the lower zone. Fig. 4 illustrates its use during a regular removal job. By this method, expensive and lengthy plug-backs with sand, gravel, and cement are eliminated. Also, the plug is set while the well bore contains oil from the recently completed lower zone, thereby preventing the mud and water from contacting the lower zone after it has been shot, which is necessary when the well is killed with mud to prepare for a plug-back. This plug is run on tubing or cable tools and engages in a recessed collar situated at a predetermined point in the casing string. Its removal is accomplished by striking one or more sharp blows with a cable-tool bit, which shears the pins holding the plug to the springs. It then falls to the bottom of the hole where it can be drilled-up or disregarded.

Variations in Well Completions

The availability of a drillable metal has made possible many new and varied well-completion processes. It has always been the operator's desire to complete his well by open hole methods or to approach that objective as closely as possible. The availability of a drillable metal permitted many operators to utilize it in such a fashion as to approximate that desire. This was possibly due to the metal's ease of removal by conventional drilling methods making it possible to regain readily an open-hole condition. It also provides insurance on

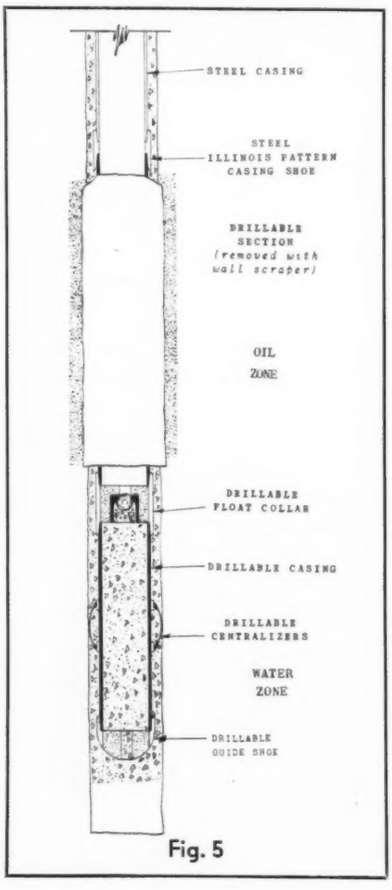


Fig. 5

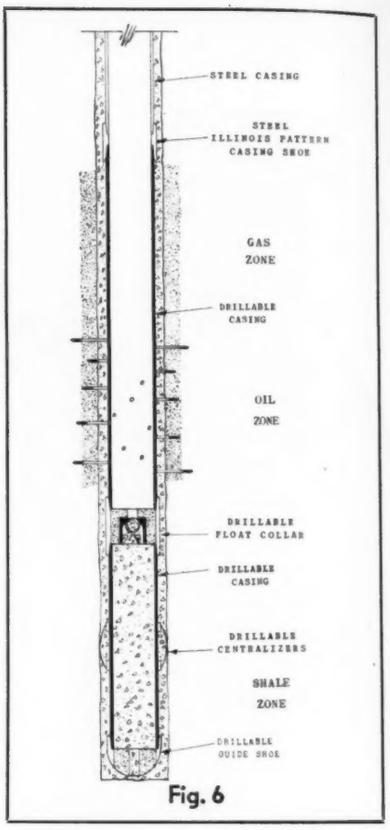


Fig. 6

the well's future productive life by eliminating costly reconditioning jobs in removing steel hazards from the hole.

Fig. 5 shows a well completion wherein the operator had drilled too deeply and encountered water. In place of the customary plug-back with drill pipe, the operator chose to run a full string of casing to bottom with the lower part composed of drillable casing. By removing only that part of the metal opposite the oil sand, a permanent cement plug was left in the hole opposite the water sand. This method of plug-back was preferred over customary practice as it permitted cement to be circulated at the point where uncontaminated cement was most desired and leave clean cement to provide a good hard plug. The presence of the drillable casing in no way hindered the operations for, if at some future date it is desired to deepen the well, a full gauge hole can always be restored by drilling methods.

The presence of gas caps in recently discovered areas has led to the development of another technique. Fig. 6 shows the completion method employed. Drillable metal was run on the bottom of the casing string and set through the entire gas and oil zone. As the gun-perforation progressed upwardly, the increase in gas-oil ratio could be readily detected at the sur-

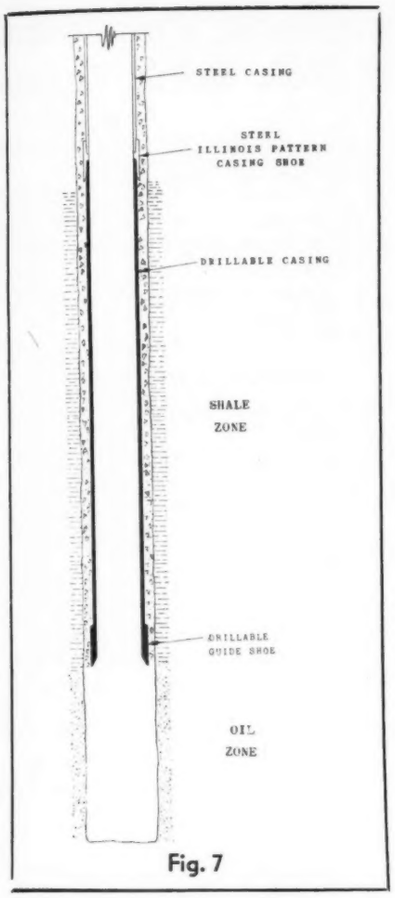


Fig. 7

face and the drillable metal removed to that point. Later, as the gas is depleted, the remaining portion of the drillable metal can be removed and the entire formation reshot, thereby recovering any oil remaining in the upper gas portion of the sand. A well completed in this manner can also be deepened by drilling-out the cement plug and drillable metal at the bottom of the hole.

It has been previously mentioned that the producing zones normally require shooting to cause them to produce efficiently, and in this connection one operator used an interesting well-completion method. It is not uncommon to encounter small thicknesses of producing sands with thick overlying shale beds. This requires the operator to set his casing directly on top or possibly a foot or two into the sand, leaving very little space for shot placement, and numerous cases of damaged casing have resulted. Although some operators resort to the use of heavier casing at the lower end of the casing section as a protection against the shot, one operator uses the well-completion method as shown in Fig. 7. The drillable casing is run on the bottom of the steel casing and set on top of the oil sand. If the shot tamp fails to hold and the casing is damaged, the drillable metal can be swedged-out easily, or if severely damaged, removed and a smaller diameter liner run. This eliminates prolonged milling and swedging jobs on damaged steel casing.

Another interesting variation from standard methods is illustrated in Fig. 8. Due to the small amount of shale (sometimes 5 to 10 ft.) present between some producing zones, drillable metal is placed on the lower end of the casing string, extending from the top of the upper zone to the top of the lower zone. Only the drillable casing opposite the upper sand is removed, and a drillable metal liner is left between the zones. As these sections are short in length, it is believed that channeled cement or the placement of a small amount of cement in the annulus might permit this section to become unseated at some future date. Being of drillable metal this liner section could be easily removed, whereas a steel section, if it became loose, might cause an expensive fishing job or loss of the hole.

Many other departures from these procedures can readily be visualized depending upon the pool conditions and the operator's desire. It is of worth to note that drillable and other alloyed metals have greatly increased the flexibility of completion methods and that many more possibilities are available to the industry than heretofore.

Statistical Review

That the use of drillable metal has become widespread in the Illinois-Indiana-Kentucky areas is seen in the following tabulation:

Pools	*Number of installations*	*Number of wells*
Illinois		
Albion	1	1
Centralia	2	2
Cisne	1	1
Clay City	2	2
Cowling	1	1
Crosville	5	3
Dix	2	1
Gallatin County		
Wildcat	2	1
Hamilton County		
Wildcat	2	1
Keensburg	7	5
Loudon	22	22
Mills Shoals	2	2
North Noble	16	16
Salem	13	13
Indiana		
Griffin	39	27
Heusler	8	7
New Harmony	5	3
Kentucky		
Birk Dome	2	2
Hopkins County		
Wildcat	4	1
Total	136	111

Thirty-five operators made use of drillable metal during the year 1939 in these various localities.

Drillable metal has recently been employed by a service company for the manufacture of bailers. These bailers are for use in placing gypsum cement plugs and shot tamps. As the cement is of the quick-setting type, the use of drillable metal bailers insures the operator against loss of the hole if the bailer becomes accidentally cemented in the casing string. Since the inauguration of this service, one accidentally cemented bailer has been removed by cable tools without trouble.

Reviewing the progress made during the last year by operators in the Illinois Basin in the use of drillable metal, it will be observed that by its prudent use, twin well drilling for multiple sands has been greatly reduced. This has meant larger profits to the operator in reducing his investment cost. It has permitted the adequate testing of doubtful formations that were cased-off in testing lower sands. A method of reducing high gas-oil ratios has been made possible by the insertion and supervised removal of drillable metal in casing strings, and finally, better bottom-hole cement plugs for water shut-offs are more easily obtained.

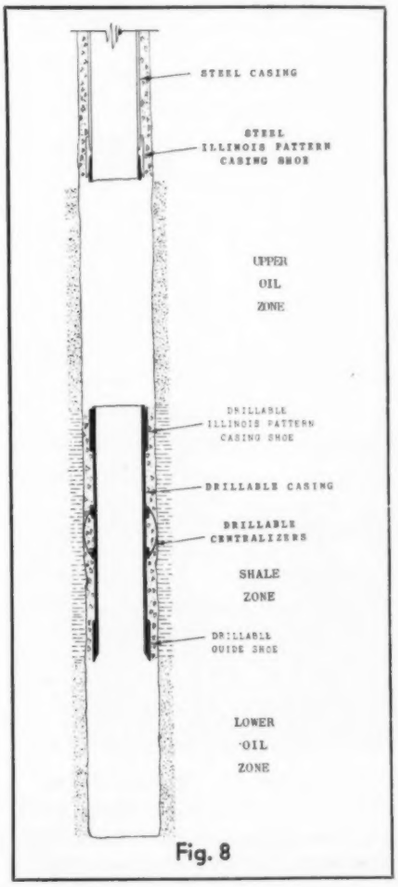


Fig. 8

Program — Tenth Mid-Year Meeting American Petroleum Institute . . . May 27-31, 1940, Fort Worth, Texas

Wednesday, May 29

9:00 A.M.

DIVISION OF PRODUCTION

Drilling Practice: (Blackstone Hotel—Venetian Ball Room).

(Sponsored by the Central Committee on Drilling and Production Practice).

Papers on the following subjects will be presented:

"Summary of Existing Data on Collapsing Strength and Setting Depths of Casing."

"Accident Prevention and Safety Measures on Drilling Rigs."

"Depth Measurement by Means of Multiple-Strand Wire Lines."

9:30 A.M.

DIVISION OF REFINING

Refinery Problems: (Texas Hotel—Crystal Ballroom).

"Selection of the Most Economical Pipe and Valve Size and Rate of Flow in Piping Systems," by S. P. Johnson and F. L. Maker, Standard Oil Company of California, San Francisco, California.

"Application of Superheated Steam to Combination-Unit Prime Movers," by A. E. Harnsberger, The Pure Oil Company, Chicago, Illinois.

"Some Factors Influencing the Efficiency of Filter Clays," by L. M. Henderson, C. M. Ridgway, and W. B. Ross, The Pure Oil Company, Chicago, Illinois.

"Practical Removal of Sulfuric Acid by Bubble-Phase Absorption," by D. W. Bransky and F. F. Diwoky, Standard Oil Company (Indiana), Whiting, Indiana.

10:00 A.M.

Board of Directors Meeting: (Blackstone Hotel—French Room).

12:15 P.M.

GENERAL SESSION—LUNCHEON

General Session: (Blackstone Hotel—Venetian Ball Room).

Address: Hon. Bruce Barton, president, Batten, Barton, Durstine and Osborn, Inc., New York, New York; Member of Congress (New York).

NOTE: Tickets may be obtained at the Institute's registration desk or at the door. The cost is $1.00 per person.

2:30 P.M.

DIVISION OF PRODUCTION

Drilling and Production Practice: (Blackstone Hotel—Venetian Ball Room).

(Sponsored by the Central Committee on Drilling and Production Practice).

Papers on the following subjects will be presented:

"Practical Utilization of Rate-of-Penetration Drilling Data."

"Hydraulics of Mud-Circulating Systems."

"Engine Cooling."

"Prevention and Removal of Paraffin Accumulations."

2:30 P.M.

DIVISION OF REFINING

Refinery Corrosion: (Texas Hotel—Crystal Ball Room).

"Corrosion of Copper and Copper-Base Tubing in Oil-Refinery Heat-Transfer Equipment," by R. A. Wilkins, E. S. Bunn, and W. Lynes, Revere Copper and Brass, Inc., Rome, New York.

"Copper Alloys and Their Application in Petroleum Refining," by James T. Kemp, American Brass Company, Waterbury, Connecticut.

"Results of Corrosion Tests in Oil Refineries," by N. W. Mitchell, Chase Brass and Copper Company, Waterbury, Connecticut.

"The Method of Testing Alloy Tubes and the Use of Inhibitors," by F. M. Barry, Scovill Manufacturing Company, Waterbury, Connecticut.

"Testing of Non-ferrous Alloys for Condenser-Tube Service Under Conditions Simulating Actual Industrial Service," by R. W. Moore and S. Kleinheksel, Socony-Vacuum Oil Company, Inc., New York, New York.

"The Cathodic Protection of Condensers and Coolers Utilizing Brackish Bay Water," by N. F. Myers, W. A. S. Wright, and J. H. Brooks, Union Oil Company of California, Los Angeles, California.

"A Discussion of Some Controlling Factors in Corrosion of Heat Exchangers and Condensers," by R. L. Duff, Standard Oil Development Company, Elizabeth, New Jersey.

Thursday, May 30

9:30 A.M.

DIVISION OF PRODUCTION

Materials: (Blackstone Hotel—Venetian Ball Room).

(Sponsored by the Central Committee on Drilling and Production Practice).

Papers on the following subjects will be presented:

"Importance of Heat Treatment."

"Galvanic Corrosion of Dissimilar Metals in Salt-Water Solutions."

"Correlation of Corrosion-Fatigue Values of Steel and Sucker-Rod Performance."

9:30 A.M.

DIVISION OF REFINING

Fuels: (Texas Hotel—Crystal Ball Room).

"Significance of the Doctor Test for Gasoline," by John Happel and S. P. Cauley, Socony-Vacuum Oil Company, Inc., Brooklyn, New York.

"Performance Testing of Motor Fuels; Development of Conversion Formulas for Values by Various Methods," by Herschel G. Smith, Gulf Oil Corporation, Philadelphia, Pennsylvania.

"Knocking Octanes," by H. W. Field and C. H. Van Hartesveldt, The Atlantic Refining Company, Philadelphia, Pennsylvania.

2:00 P.M.

DIVISION OF PRODUCTION

Well Spacing and Production Technology: (Blackstone Hotel—Venetian Ball Room).

(Sponsored by the Central Committee on Drilling and Production Practice).

Papers on the following subjects will be presented:

"Basic Factors that Must Be Considered in Evaluating Reservoir Performance."

"Optimum Spacing of Dolomite Acreage in the Texas Panhandle."

"Effect of Formation Permeability on the Plastering Behavior of Mud Fluids."

"Use of Chemicals in Reducing Water-Oil Ratios."

2:30 P.M.

PUBLIC RELATIONS—GROUP SESSION

Public Relations: (Texas Hotel—Longhorn Room).

"Advertising as a Factor for Good Public Relations," by Paul Truesdell, Universal Oil Products Company, Chicago, Illinois.

"The Difference Between Impressions and Facts," by Dr. Claude Robinson, Opinion Research, Inc., New York, New York.

Motion Picture—"Building the West," courtesy of Standard Oil Company of California, San Francisco, California.

BAKER

CEMENT RETAINER

CASE STUDY NO. 404

A Case Study of an Actual Well Repair Problem Solved by Using the Baker Cement Retainer.

PROBLEM: *To Repair Split in Casing Through Which Shale Was Entering and Hampering Pumping Operations.*

METHOD: *Set Baker Cement Retainer above Casing Split and Do Squeeze Job. (A Cement Bridge was Placed at Top of Producing Zone.)*

RESULT: *100% Successful.*

• DETAILS •

Field: Salem, Illinois

Depth of Well: 1855'

Depth Retainer Set: 1760'

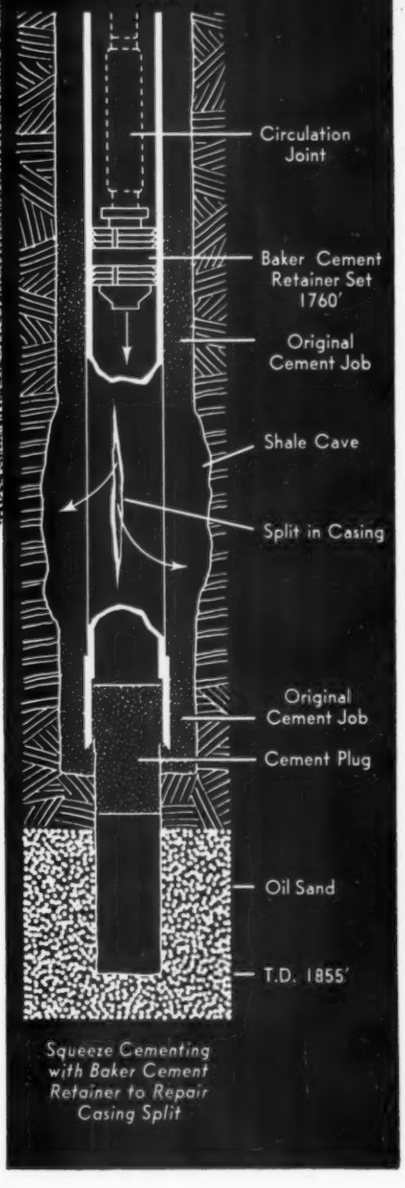
Breakdown Pressure: 800#

Final Pressure: 1000#

Number of Sax Mixed: 30

Number of Sax Put Away: 30

How Cement Discharged: through Casing Split in Shoe Joint.



Squeeze Cementing with Baker Cement Retainer to Repair Casing Split

"For Friendly Service, and Dependable Products, Specify BAKER."

BAKER CEMENT RETAINER — SAVE A WELL

PROGRESSIVE OPERATORS are depending more and more upon the Baker Cement Retainer to solve the many ordinary and complex problems arising in connection with present-day cementing, well repair and well completion operations. If you have not investigated the Baker Cement Retainer it will pay you to do so now.

Complete details concerning the many important field applications for this tool will be found on pages 239-249 of the Baker Section of the 1940 Composite Catalog . . . also in the Baker Broadcast No. 17-A, a comprehensive 40-page illustrated treatise which will be sent to any oil man upon request.

BAKER OIL TOOLS, INC.

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IMPORTANT BAKER CEMENT RETAINER APPLICATIONS INCLUDE:

Re-Cementing • Cementing Behind Sections of Pipe • Reducing Gas/Oil Ratios • Series Cementing
Plugging off Bottom Fluids • Plugging Back to Upper Zones • Testing Upper Cased Formations
Squeeze Jobs • As a Heaving Plug • As a Bridge Plug at any Place in Casing or Liner

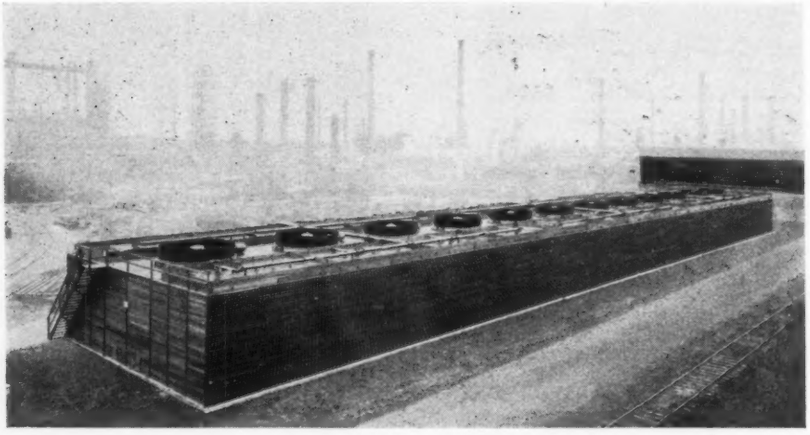
BAKER CEMENT RETAINER

MACHINERY and EQUIPMENT

Marley's Double-Flow Tower

THE Marley Company, Kansas City, Kansas, announces a new type of cooling tower of patented design especially developed for heavy-duty, large-capacity service.

The increased efficiency credited to the equipment by the manufacturer is said to be due chiefly to the tower's unusual design, an improvement over the induced-draft type. Recirculation of hot saturated used air is impossible in the new unit, mixture of water with moving air is uniformly complete throughout the interior area, and air flow is without turbulence as it is horizontal from both sides to the center chamber from whence the top fans expel it.



Operating economies are mainly attributed to reduction in pumping costs due to exceptionally low height of the tower and a distribution system that requires no pressure.

Other advantages ascribed to the new tower are freedom from "icing-up" in winter; a water distribution system that is entirely external, simplifying inspection and maintenance; better use of ground areas on crowded plant sites; in addition to Marley's typical all-bolted, diagonally-braced, extra rugged construction.

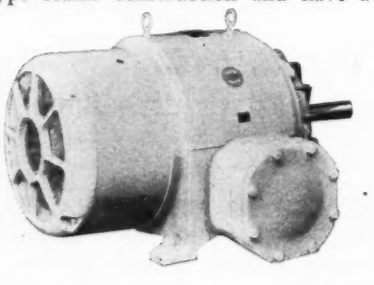
Sizes of existing installations range from single-fan units of 2000 gal. per min. to one tower having twelve 13-ft. fans and another with 14 fans under construction. Marley 24-page Bulletin 602, illustrated with photographs and diagrams, is devoted entirely to the "Double-Flow Tower," as the new type has been named.

Large Size U. S. Explosion-proof Motors Now Available

HIGHER horsepower explosion-proof motors are now offered by U. S. Electrical Motors, Inc., Los Angeles, California, and Brooklyn, New York.

In Class I, Group D explosionproof motors, approved by National Board of Fire Underwriters, the ratings have been increased from 25 to 75 hp., whereas in Class II, Group G they have been increased from 7½ to 75 hp.

The larger motors are of the shell type frame construction and have a specially designed fan that is quiet even at high speeds. Wiring is made more convenient by a new larger terminal box. For example, the cubic content of a 40 hp., 1800 r.p.m. explosionproof motor is 600 cu. in.



The fan-end inner end bell and the outer fan cover bracket are held in place by a simplified type combination screw. This construction eliminates one set of holding screws and supplies rigid and secure mounting for the fan cover and bracket, as well as facilitating the assembly or disassembly of the motor. Write for bulletin: U. S. Electrical Motors, Inc., Dept. 106, 80 Thirty-fourth Street, Brooklyn, New York.

Elastic Stop Nuts Available in Various Combinations

ELASTIC Stop Nut Corporation, 1015 Newark Avenue, Elizabeth, New Jersey, announces that, in addition to its standard line of self-locking nuts, these nuts can now be supplied on order in any metal and in any combination of style, size, and thread system. Elastic Stop Nuts incorporate a resilient non-metallic collar that takes-up all thread play, thus establishing a constant thread contact that holds the nut in position on the bolt regardless of vibration or wear of surrounding parts, the makers assert. They were developed originally for pneumatic tools and other apparatus subject to heavy vibration, and are now widely used on drilling, pumping, and other oil-field equipment.

Catalog, with graphic explanation of the Elastic Stop principle and listing the standard nuts available, will be sent upon request to the manufacturer.

"CLEVELANDS" TAKE 'EM IN STRIDE
—The Tough, Hard Spots or Easy Going
—The Usual or the Unusual!

MODEL 140

On transmission and main lines—scattered field and gathering lines—"hot-spot" reconditioning or taking up existing lines—stripping pipe—wherever you put them, "Clevelands" field-tested in all soils . . . loose sand, sticky gumbo or rocky ground . . . deliver maximum footage, meeting conditions as they are.

Soundly engineered, ultra-modern in design with waste motion done away with and dead weight and unnecessary bulk eliminated, "Clevelands" are built to "take it" day in and day out, taking the usual and the unusual right in stride. They're the type of ditcher you'll find a pleasure to own and operate. Write for specifications and details today.

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"Pioneer of the Small Trencher"
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1/8" TO 3/4" PIPE
5/16" TO 1" BOLTS

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DEEP—STANDARD—SHALLOW THREADS

—are easily produced with "TOLEDO" Adjustable Pipe and Bolt Die Heads.

Simple, positive adjustment of 4 to 5 turns on pipe and 1/64" on bolts. Loosen 4 cover screws and turn knurled ring until desired size is reached.

Dies can be reground or replaced at small cost. All segments cut equal even when standard setting is changed.

For repair work and where threads must be hidden, these "TOLEDO" heads are of real value.

Any combination furnished. Ratchet handle or two-handle stock if desired. Your dealer can supply you or write us for further details.

THE TOLEDO PIPE THREADING MACHINE COMPANY
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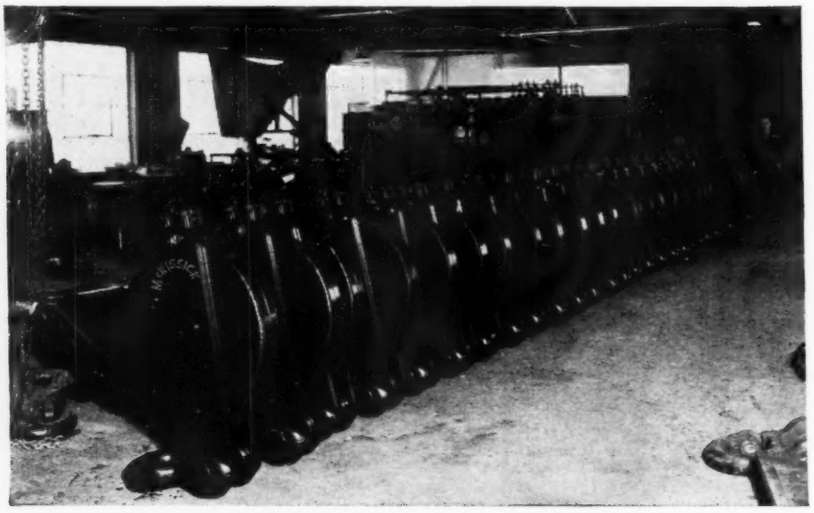
Single-Sheave Tubing Blocks

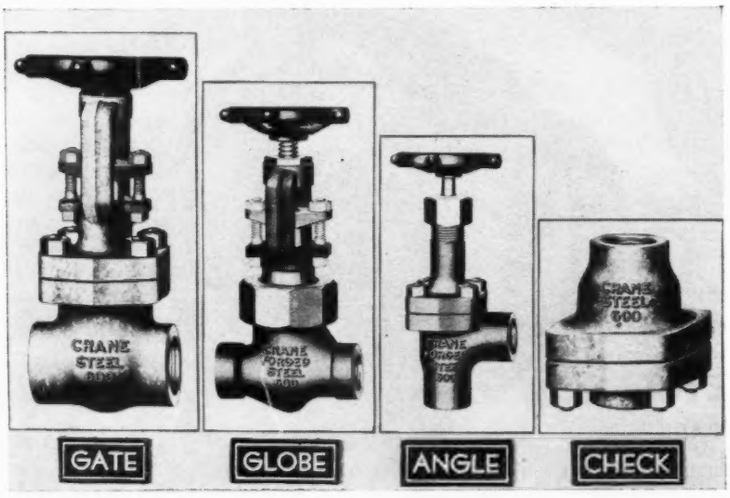


THE accompanying illustration shows 30 single-sheave tubing blocks with 26-in. diameter sheaves, shipped to the Argentine Government on March 28, 1940. The blocks averaged 1020 lb. each, and the total weight of the shipment, boxed for export, was 36,871 lb. This is one of the largest single tubing block orders ever produced by the McKissick Products Corporation, Tulsa, Oklahoma.

Crane Small Steel Valves

A RECENT development in the field of small steel valves for steam and oil service is a new line by Crane Co., Chicago, Illinois.

To satisfy all service requirements to which such valves may be subjected, this new line includes gates, globes, angles, and checks, in sizes ¼ to 2 in., inclusive, and embodies both inside screw and O. S. & Y. construction, union and bolted bonnets, screwed, socket weld, and flanged ends. In all, there are 176 valves of the types mentioned.



The valves are "tailor-made" for their particular applications. Each type is given individual attention from start to finish, resulting, according to the makers, in an entirely new line of valves including the following:

1. Gate valves made of cast steel with O. S. & Y. construction, having union bonnet in sizes ¼ to ¾ in., inclusive, and bolted bonnet with screwed, socket weld, and flanged ends in sizes ½ to 2 in., inclusive (½ in. and ¾ in. are available in both union and bolted bonnet).

2. Globe and angle valves made of forged steel in two types: Inside screw and O. S. & Y. construction. Inside screw valves have screwed ends with union bonnet in sizes ¼ to ¾ in. inclusive, and bolted bonnet in sizes 1 to 2 in., inclusive. O. S. & Y. valves have screwed ends with union bonnet in size ¼ to ¾ in., inclusive, and screwed, socket weld, and flanged ends with bolted bonnet in sizes ½ to 2 in., inclusive (½ in. and ¾ in. are available in both union and bolted bonnet).

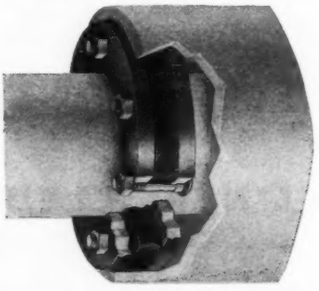
3. Check valves also made in two types: the horizontal pattern is forged steel with union cap and screwed ends in sizes ¼ to ¾ in., inclusive, and with bolted cap and screwed, socket weld, and flanged ends in sizes ½ to 2 in., inclusive (½ in. and ¾ in. are available in both union and bolted cap). The vertical ball pattern is cast steel with bolted joint and screwed ends in sizes ½ to 2 in., inclusive.

It will be noted from the accompanying illustrations that these valves are unusually compact and rugged. Some are forged; some are cast.

The castings for the gate valves and the vertical ball pattern check valves, however, are an innovation in steel foundry practice in the valve and fitting industry, it is stated. Carefully compounded from selected raw materials, this steel is melted by high frequency induction methods with exacting control of composition and temperature. The result is radio-cast steel, so-called because of the development and control of foundry technique and periodic x-ray and gamma ray radiographic inspection of castings.

Simple, Quick Closures Between Casing and Pipe

A PRACTICAL answer to the problem of sealing the ends of a protective casing through which a pipe line runs, is now offered by the new Dresser Casing Bushing, according to the Dresser Manufacturing Company, Bradford, Pennsylvania, its maker. Consisting of two halved steel rings with a rubber-compound gasket bolted between them, this bushing is said to be easily assembled around pipe and slipped into ends of casing to provide a simple, quick closure. The working principle is described as simple and effective: as bolts are tightened, the



Cutaway view showing working principle of the Style 83 Casing Bushing; how it forms a closure between the pipe and casing when installed. Type I is shown.

gasket expands outwardly against the inside of the casing and inwardly against the outside of the pipe, making a tight seal against both. Casing bushings are suggested for any line where protective casing is used, as under a railroad track, highway, embankment, or across a swamp, canal, irrigation ditch, or stream.

Numerous advantages are given by the manufacturer for the casing bushing, known as Style 83. It is said to prevent dirt, debris, weeds, small animals, and corrosive water from entering the casing thereby prolonging pipe life because pipe is kept dry and clean. It "floats" the pipe line in the casing; vibration and shock from passing trains and traffic (ordinarily relayed to pipe) are absorbed by the resilient rubber gasket. It centers the pipe line in the casing; pipe does not rest on bottom of casing where corrosion may develop and coating be scraped off. Quickly and easily installed by one man using only a wrench, the casing bushing is declared to eliminate crew back-tracking, open trench, and costly sealing methods and materials (cement, gunny sacks, wood blocks, sandbags, etc.).

The Style 83 casing bushing is offered by the maker in four types to meet varying field conditions. Types 1 and 2 take care of all ordinary installations when there is no pressure between pipe and casing. Types 3 and 4 are designed for installations when such internal pressures may occur, or when the line is subject to heavy ground settlement or to strong currents or undertows (on subaqueous lines). Any size can be supplied.

A two-page catalog (form 402) gives complete information, specifications, sizes, and list prices.

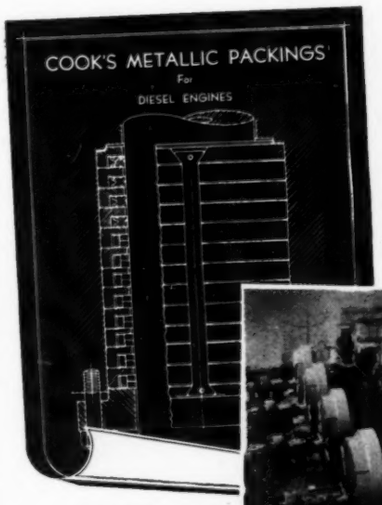
Rex Mud Conditioner

CHAIN Belt Company, 1600 West Bruce Street, Milwaukee, Wisconsin, announces the manufacture of the Rex Mud Conditioner. The equipment incorporates a number of features that make it an outstanding unit for the removal of shale, sand, and cuttings from rotary drilling mud, according to the manufacturer. Some of these features are:

A 20 sq. ft. screen area, a screen that stretches crosswise and lengthwise eliminating dead spots, cushion rubber screen cloth support, stainless steel screen cloth, oil-lubricated vibrator, and feed control gates.

The new Rex Mud Screen is a low head-room, compact unit ruggedly built complete in itself and easily moved from one location to another.

On the tough jobs . . .



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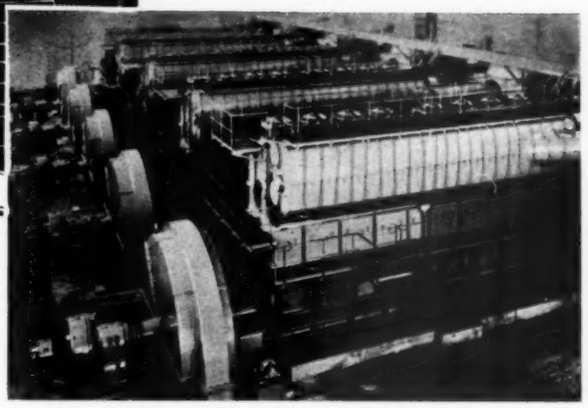

A battery of 35000 H. P. Double-Acting Diesels — All COOK-equipped.

For example -- *every double-acting Diesel built in America is fitted with COOK'S Packing!*

THE universal selection of COOK'S Metallic Packing for the **tough** jobs—jobs, like double-acting Diesels, that demand the best in engineering and materials—is the finest recommendation that could be given COOK'S Packings. It proves that equipment manufacturers know COOK'S Packings assure **maximum performance at minimum expense.** And just as COOK'S Packings lead in the Diesel industry, they lead—and have led for over 50 years—in the Industrial field generally. When ordering **new** engines or compressors make sure you get the genuine—specify "COOK'S Metallic Packing" by name. For installed equipment, order from the equipment maker or from us direct.

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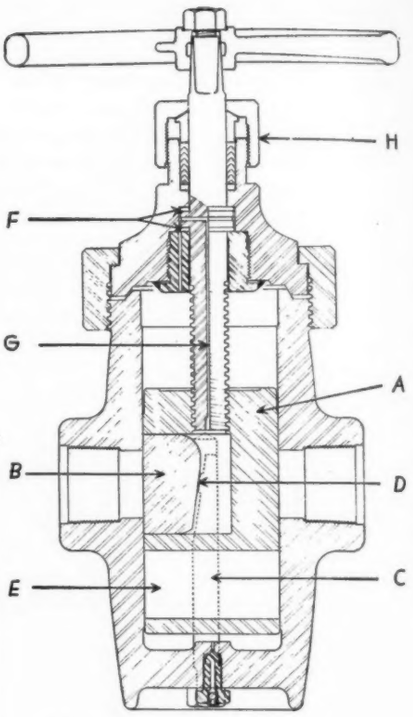
INCORPORATED
New York Cleveland Los Angeles Baltimore LOUISVILLE, KY. Chicago Tulsa New Orleans San Francisco

O-C-T Announces Type "V-3" Gate Valve

OIL CENTER Tool Company, Houston, Texas, is now marketing its new Type "V-3" Double Seal Cylinder Gate Valve, which, according to its designers, A. J. Penick and K. T. Penick, employs an entirely new means of sealing and lubrication.

As shown in the cross-sectional view herewith, the gate (A) of the O-C-T valve is cylindrical and travels in the round bore of the valve body. A tapered sealing segment (B) is inset in one side of the gate piston. A taper is machined on the backside of this segment to mate with the taper on two wedge pins (C), which are attached to the bottom of the valve body and which extend into the gate piston. Upon closing the gate, the tapered side of these pins contacts the taper on the sealing segment at its center point (D), resulting in an equalized outward thrust in two directions, i.e., against the sealing segment in one direction and against the gate piston in the opposite direction. Thus, the convex sealing surfaces of both the segment and piston are forced into sealing contact with the inside wall of the valve body.



All moving parts of the valves are lubricated each time it is opened or closed. When the valve is in open position, the bottom of the valve body serves as a reservoir for lubricant. Upon closing the valve, the lubricant is forced upward through four grooves on the outside of the gate piston, automatically lubricating the cylinder and piston, so that when the valve is in closed position the upper part of the valve body serves as a reservoir for the lubricant. When the valve is opened, grease is forced to the outside of the thrust bearing (F) through passages drilled through the retainer nut. Closing the valve forces lubricant to the inside of the thrust bearing by means of a passage (G) drilled through the gate stem. A special plug with grease gun connection is provided in the bottom of the valve body should it ever become necessary to replenish the lubricant. An efficient seal around the gate stem is provided by V-type graphited asbestos packing in a stuffing box (H) above the bonnet.

The entire valve is made of alloy steels particularly suited for this purpose.

"MANZEL" MODEL "94" FORCE FEED LUBRICATORS *for* MOST EFFICIENT *Diesel Lubrication*

7-Pint, Three-Feed, Left-Hand Ratchet Drive, Model "94" With Horizontal Outlets

"Manzel" Model "94" Lubricators meter out the oil to the engine with clock-like precision and deliver it to the cylinders with unfailing regularity.

Single plunger pumping units draw the oil from the reservoir and force it through the liquid filled sight feed glasses, directly to the points to be lubricated. The amount supplied by each feed is clearly shown in the sight glass after it has passed through the pumping mechanism and is actually on its way to the cylinder.

Each pumping unit is individually regulated and capable of very fine adjustment. Individual pumping units are easily removed for inspection or replacement without interfering with other units or stopping the lubricator.

All working parts are completely enclosed and operate in a bath of oil.

Can be supplied with one to twenty-four feeds—rotary or ratchet drive.

When ordering your new Diesel engine be sure to specify that it be equipped with "Manzel" Model "94" Lubricators.

CATALOG NO. 94-B GIVES FULL DETAILS

MANZEL BROTHERS COMPANY
291-293 BABCOCK STREET BUFFALO, N. Y.

Fisher Interface Liquid Level Controller

FISHER Governor Company, Marshalltown, Iowa, recently announced a new liquid level controller designed to maintain a liquid level when two liquids of different specific gravities are involved. This new controller holds the level of the heavier or

lower liquid at a predetermined point and operates a diaphragm control valve to drain off that liquid as it accumulates in the tank.

The difficulty of level control when the difference between specific gravities of the two liquids is very slight is one of the problems that frequently confronts the oil refiner. Fisher Type 246-P Interface Level-Trol is especially adapted to meet the need for this type of control, the manufacturer asserts. It can be supplied with various size floats to meet various conditions of specific gravity.

Further information concerning Type 246-P can be obtained by writing the Fisher Governor Company.

Lufkin Inside Micrometers

THE Lufkin Rule Company, Saginaw, Michigan, has placed on the market No. 80 Series Inside Micrometers. These micrometers are substantially lower in price than the Lufkin

No. 680 Series. They are designed for those mechanics not requiring some of the features found only in the No. 680 line.

On these inside micrometers provision is made for adjusting tension and taking-up wear on the screw. Contact points of the rods are adjustable for maintaining their individual length. All contact points are hardened and ground. A handle can be supplied on either of these tools and either can be supplied with plush-lined case.

CORRECTION

The following changes should be noted in connection with the publication of "Methods of Studying Microbiological Anaërobic Corrosion of Pipe Lines" by Raymond F. Hadley, appearing in the March and April issues of *The Petroleum Engineer:*

On p. 171, March, 1940, issue: The last column in Table 1 should be headed:

Of that pipe requiring protection, 1936-43. Percentage due to bacterial attack.

On p. 172, March, 1940, issue: The correct caption for Fig. 1 is:

Typical short swamp in which microbiological anaërobic corrosion may be expected. Note abundance of organic materials found in trench.

On p. 173, March, 1940, issue: The correct caption for Fig. 2 is:

Photograph of pipe at site illustrated in Fig. 1. Heavy incrustation of corrosion salts includes ferrous sulphides.

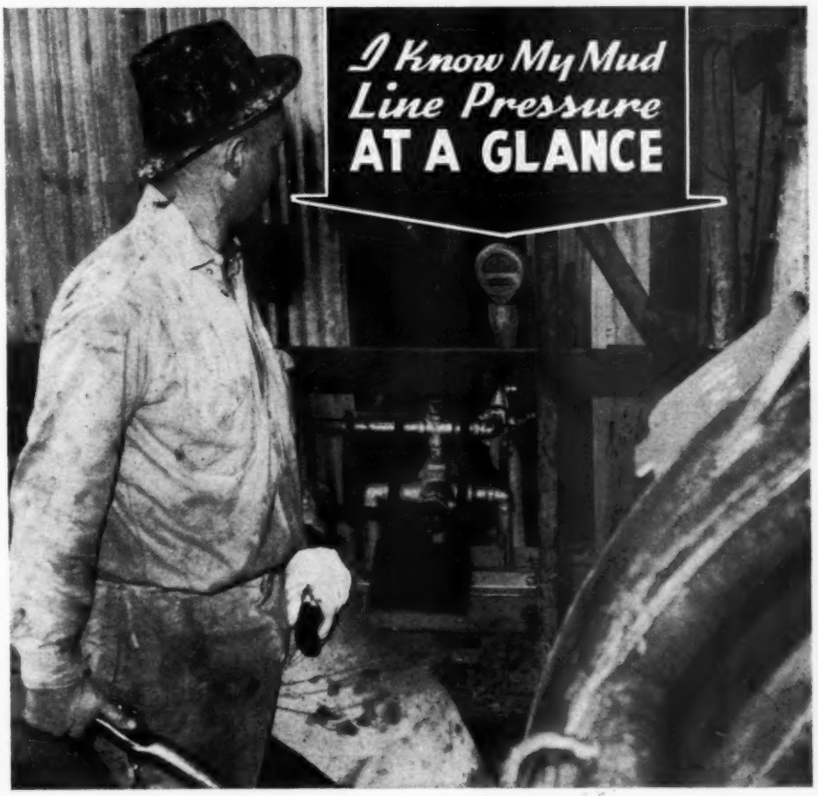
On p. 114, April, 1940, issue: The correct caption for Fig. 3 is:

Photograph illustrating the visual appearance of the three actively corroding metal specimens.

On p. 116, April, 1940, issue: The correct caption for Fig. 4 is:

Mixed culture of microörganisms used in corrosion experiment. Note presence of sulphate-reducing Vibrios. X675.

The correct caption for Fig. 5 is: *Sporovibrio desulfuricans* third transfer of enrichment culture in lactate medium. X675. Original enrichment culture grown from products of corrosion on 6-in. mild-steel pipe line in York County, Pennsylvania.



He, like thousands of other drillers, knows the value of this revolutionary oil industry pressure gauge. He reads, at a glance, the large scale figures entirely across the derrick floor. It's a steady reading because the gauge is free from the violent fluctuations common to ordinary pressure gauges, and unaffected by external vibrations.

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PRESSURE GAUGE

Baker Retainer Production Packer

TO meet the problem of multiple-zone production when oil from different sands must be kept segregated, the Baker Retainer Production Packer has been designed by Baker Oil Tools, Inc., Los Angeles, California, to pack-off between two producing zones and produce them separately. Production from the lower zone is through tubing run through the packer; production from the upper zone is through the annular area between the tubing and the liner or casing. When production from three zones is to be kept separate, an additional packer is used.

The packer is supplied in three designs: the packing head seal type, the continuous double seal type, and the continuous single seal type. All types are of the same basic construction but with individual features providing for raising and lowering the tubing to regulate flow and gas-oil ratios, to clean-out sand, to wash over, to swab-in the different zones, or to shut-off the bottom producing zone.

The construction of the Retainer Production Packer, packing head seal type, is shown in Fig. 1. It is run into the hole on a setting tool. At the top

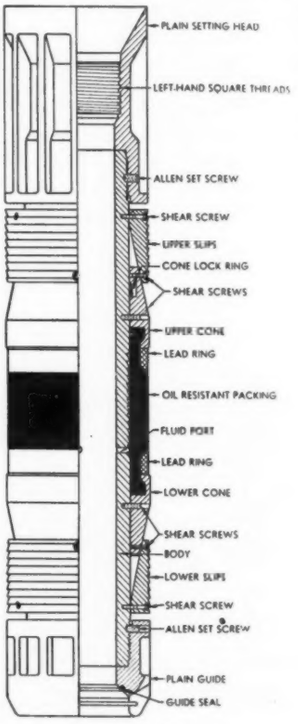


Fig. 1

of the packer is a plain setting head equipped with left-hand square threads into which are screwed corresponding left-hand square threads in the head of the setting tool. The setting tool is at-

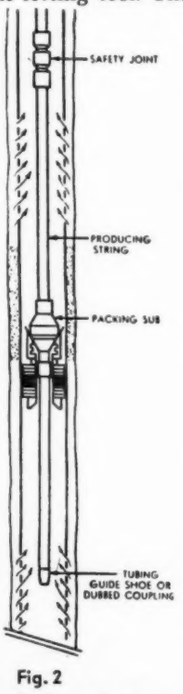


Fig. 2

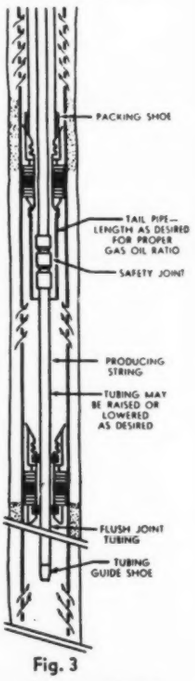
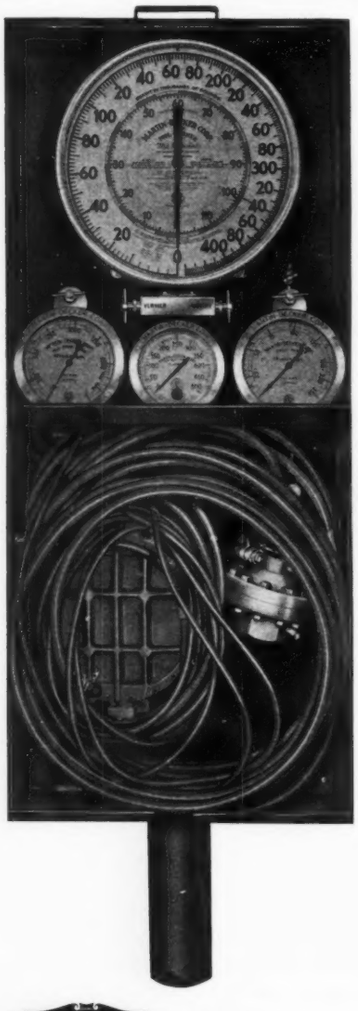

PACKING SHOE
TAIL PIPE—LENGTH AS DESIRED FOR PROPER GAS OIL RATIO
SAFETY JOINT
PRODUCING STRING
TUBING MAY BE RAISED OR LOWERED AS DESIRED
FLUSH JOINT TUBING
TUBING GUIDE SHOE

Fig. 3

tached to the bottom of a running-in string, usually consisting of tubing, which is made up with an expansion joint a few feet above the setting tool.



WHEN you first get the "feel" of the "Sealtite" Drilling Control's smooth operation . . . when you see its instant sensitivity to light or heavy weight changes . . . and when you know that it'll handle the job accurately and safely all the way down whether you're going deep or shallow—*you won't want to drill without it!*

The Martin-Decker "Sealtite" tops them all when it comes to operating efficiency, accuracy and dependability. It has a completely closed and sealed fluid system that can't leak. It's more compact, easier to carry, and faster to install. It lights up at night to give perfect visibility. It has capacity to handle 20,000 foot wells. And it has a score of other important features you should know about.

Make it a point to investigate, right now, the *engineered* efficiency that's built into this *complete* drilling control instrument — efficiency that will help you make substantially more hole at less cost, *because you accurately control every foot you drill.* Your Martin-Decker or Reed Roller Bit representative has all the dope on the "Sealtite" . . . ask him for it today!

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SAN JOAQUIN VALLEY: A. F. McQUISTON, BAKERSFIELD, CALIFORNIA
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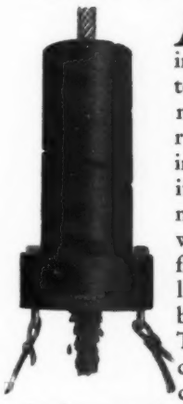
The packer is run to its predetermined position in the well and is tripped and set to seal-off against the liner or casing with an oil-resisting packing rubber between two lead seals. It is prevented from moving either up or down the pipe by two sets of slips.

The two-zone production method is illustrated in Fig. 2. Either threaded-and-coupled or flush-joint tubing can be used for the production string, made up with a packing sub to bottom the tubing at a predetermined depth. Oil from the lower zone flows upward inside the tubing. Oil from the upper zone flows upward in the annular space outside the tubing.

The three-zone production method is illustrated by Fig. 3. Any of the three types may be employed for the lower packer but the Packing Head Seal Type is used between the middle and top zones. A tail pipe of proper length is attached to the bottom of the upper packer and a packing shoe is made-up on the bottom of a flow string, to separate the production from the middle and top zones. Oil from the bottom zone flows upward through the tubing; oil from the middle zone flows upward outside the tubing but through the tail pipe, the upper packer, and the flow string; and oil from the top zone flows upward through the annular space between the flow string and the liner or casing.

Rubber Wire-Line Wiper



A NEW type of wiper has been introduced by Patterson-Ballagh engineers. It is an all-rubber unit for wiping the wire line. By its use, excess oil or mud that otherwise would drip to the rig floor is wiped-off the line cleanly and falls back into the hole. There is no metal to contact the line or create a fishing hazard, the manufacturer asserts. This wire-line wiper can be quickly removed when the tool emerges and thrown to one side. It consists of a heavy rubber sleeve and rubber flange or collar, integral. The sleeve is spirally split so that it can be distorted for insertion around the wire line. It is approximately 10 in. long by 4 in. in diameter and weighs 5 lb. When hooked into place, it is held in position by short pieces of line on either side.

Further details may be obtained from Patterson-Ballagh Corporation, 1900 East 65th Street, Los Angeles, California.

Cavins Automatic Hydraulic Suction Bailer

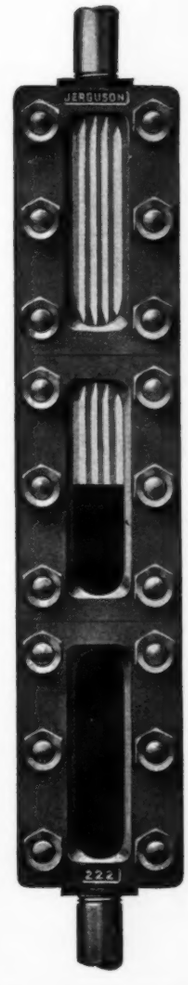
THE Cavins Automatic Hydraulic Suction Bailer, designed to be run inside of oil-well tubing on piano wire outfits, such as those used for checking well depths and doing bottom-hole pressure and temperature work, is a new product recently developed to remove sand bridges in tubing, and remove sand from the top of the bottom-hole flow beans when it is not practicable, or possible, to rig-up with regulation hoists and sand lines for standard length bailers.

The total overall length of this bailer is 10 ft. and the outside diameter is 1½ in. The complete tool weighs 31 lb. It has a total fluid capacity of ½ gal. and a net sand capacity of ¼ gal. It is made of heat-treated SAE-4140 steel and equipped with a Cavins Candee type bottom and two flat spring type safety pressure relief valves. The valve mechanism is a newly developed Cavins telescopic type valve section.

The tool is manufactured by The Cavins Company, Long Beach, California.

JERGUSON

REFLEX GAGES



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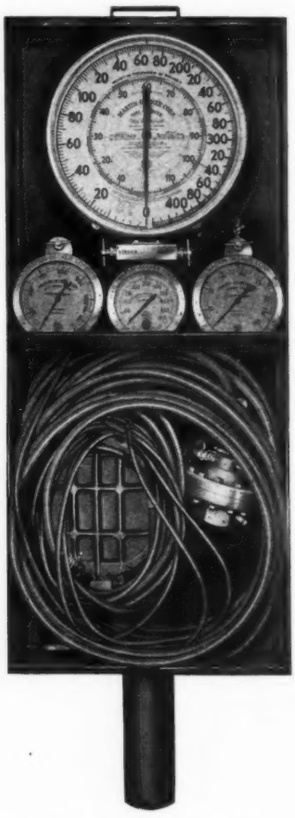
"Sealtite" Drilling Control

A NEW drilling control instrument, designed to eliminate fluid leakage, has been introduced by Martin-Decker Corporation, Long Beach, California. The instrument, known as the "Sealtite" drilling control, is assembled with steel-shielded rubber hose and steel fittings instead of the conventional copper valves and tubing, making it leak-proof and pressure-tight throughout. The entire fluid system is filled, tested, and sealed at the factory. No further pumping-up is required. Inasmuch as the instrument is connected-up and ready to install when it reaches the rig, installation time is materially reduced.

The complete instrument consists of five individual units: a "Sealtite" weight indicator with super-sensitive vernier mechanism, "Sealtite" mud pump gauge, torque gauge, tachometer, and recorder, assembled in one compact steel case. Variations in weight on bit, mud pump pressure, and torque are permanently charted by the recorder, which is mounted back-to-back with the weight indicator. This provides ample storage space in the front of the case for the rubber hose and diaphragms during transportation.

The "Sealtite" weight indicator has a capacity great enough to be used on 20,000-ft. wells. It is indirectly illuminated for easy night reading, and indicates weight directly in thousands of pounds, or points, on a 16-in. dial face. The vernier gauge hand is used for lightweight operations when extremely accurate readings are required.

The mud pump gauge, torque gauge, and tachometer are equipped with new M-D flexoglass lenses that are shock- and pressure-proof. The pump pressure and torque mechanisms operate in a bath of oil. Pump pressure readings



range to 5000 lb., and capacities of the torque gauge and tachometer are 3500 lb. and 500 r.p.m., respectively. Whenever required, special pulsation dampers are used to smooth-out the gauge readings and insure accuracy and sensitivity in rough drillings.

Type-M Drift Indicator

TO ELIMINATE the need for developing photographic drift indicator records in solutions, the Eastman Oil Well Survey Company, Dallas, Texas, and Long Beach, California, is manufacturing for distribution a new Type M drift indicator. The instrument records on light-sensitive paper that can be loaded and unloaded in

GRIZZLY ROTARY BLOCK *Band Exchange*

GRIZZLY LINED STEEL BANDS for ALL TYPES of brakes and TO FIT any drum diameter carried in stock by leading supply houses for quick delivery to your rig. Ask your supply dealer for full details, prices, etc.

This unique Grizzly service solves your brake lining problem for you—simply, economically — effecting large savings in time, labor and production. When your brake lining becomes worn, order new Grizzly bands complete, from your nearest supply house or direct from the factory. You will receive bands for your particular drawworks exactly like those on NEW machines, factory lined to manufacturer's specifications—all ready to install in exchange for your old bands. You get the CORRECT lining for your equipment, CORRECT factory installation and perfect bands that function properly. Yet the cost is no greater—you actually SAVE! Ask your supply house or write direct for details and exchange list.

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daylight. The instrument is small and compact and can be handled easily and quickly, the makers assert.

The mechanism incorporates an arrangement whereby the inclination of the well is recorded by a strong beam of light directed through the plumb-bob onto the light-sensitive paper printed with concentric circles, each of which represents a degree.

The instrument is run into the well, in a new Eastman streamlined barrel, on piano wire sandline or is dropped to bottom just before the drill pipe is pulled to change bits. The barrels are equipped with interchangeable connections for all operations and are small enough to run through tool joints in 3½-in. regular A.P.I. drill pipe.

Although not photographic in principle, the new Type M drift indicator embodies the important feature of the photographic method of recording. This drift indicator supplies a positive reading when the instrument is on bottom and still. If moving, a blurred or blank record will be the result and erroneous data can be detected, saving much lost time caused by misleading readings. The drift angle off vertical only is available with the new Type M drift indicator. Directional drift angle surveys are available with Eastman single shot and multiple shot survey instruments.

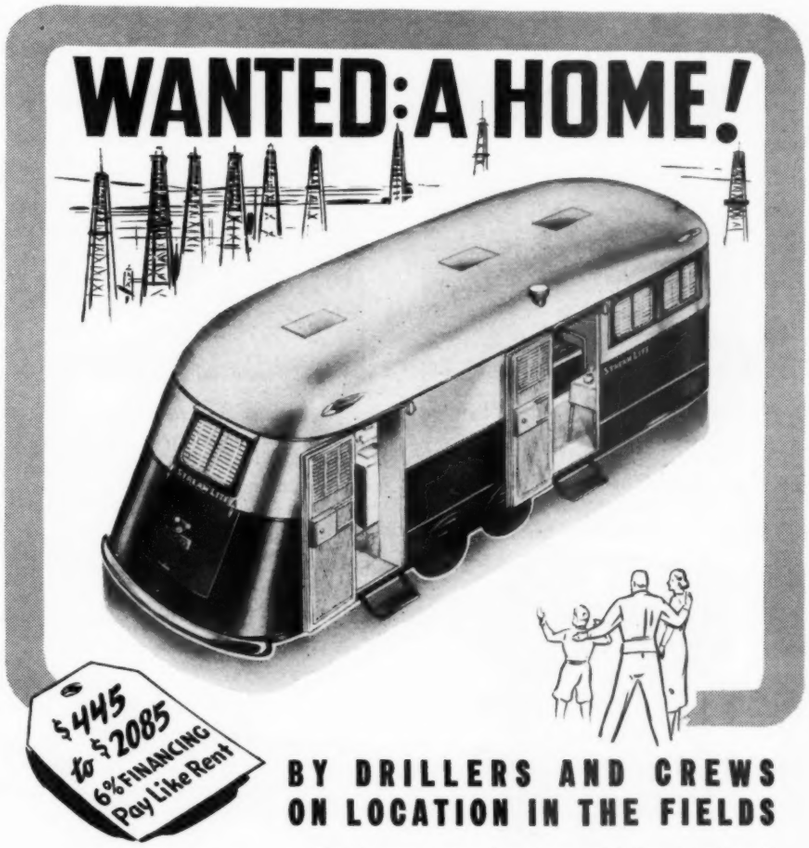
Full description, information, and instructions for operation are available from the manufacturer.

Unibolt "Flexi-Ball" Joints for Rotary Hose Connections

THORNHILL-CRAVER Company, Inc., Houston, Texas, manufacturers of Unibolt products, are now advocating the use of their "Flexi-Ball" joint on rotary hose connections to relieve strain on the hose. The "Flexi-Ball" joint was designed originally for use on high-pressure steam lines, boiler headers, mud lines and conveyors of oil, water, gas, gasoline, and air, which are subject to contraction or expansion. It is also used to simplify misaligned connections, prevent damage caused by intermittent vibration, and for flexible manifolds.

As shown in the accompanying illustration, the joint differs from the regular Unibolt "Flexi-Ball' joint only in that its hubs are threaded male by female. With a swing of 45 deg., it is obvious that such a flexible joint on both the standpipe and swivel connections will entirely eliminate the strain placed on a hose by rigid connections at those points, the manufacturer states. The ball hub member, which is provided with a male thread, would receive the flow of fluid for maximum service.

All Unibolt "Flexi-Ball" joints employ the patented Unibolt coupling principle that eliminates both threaded and flanged connections between the



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Field men, your housing problem is solved! *Stream-Lite's* mobile homes afford entirely new living possibilities for field men and their families. All the conveniences and comforts—a living room, two bed rooms to sleep four, dinette, kitchen, lavatory—truly a complete home. But it's much more convenient, because you take it right with you from job to job. No more housing worries for the man with a *Stream-Lite* home. You can pay for it as you live in it too—just like rent.

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Stream-Lite Coaches

Division of Chicago House Trailer Co.
2437 So. Michigan Ave. Chicago, Illinois

component parts of the joint. There are no threads to gall or freeze. Three-point suspension provided by the three tapered shelves, together with a radius machined in the back of the nut member, assure even distribution of pressure on the packing when the single bolt is tightened, it is asserted. Even after long periods of service, according to the manufacturer, the joint may be easily broken for repairs by simply releasing the one bolt.

Staynew Pipe Line Filter

THE new model AAPHS Protectometer Air Filter, announced by the Staynew Filter Corporation, Rochester, New York, is designed primarily for the complete removal of oil from compressed air lines. In addition, it effectively prevents the passage of moisture as well as dust, dirt, pipe scale, and other foreign matter, according to the manufacturer.

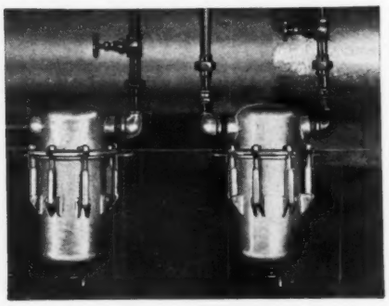


Fig. 1. Two Model AAPHS filters installed on air lines

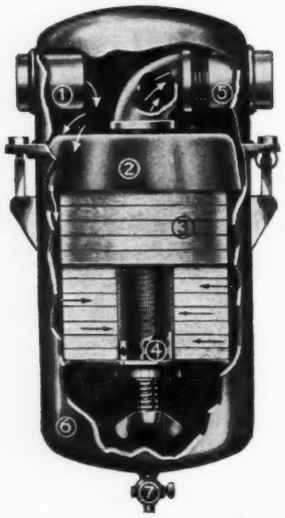


Fig. 2. Sectional view of filter

The principal feature of the new filter is a series of disks (See "3", Fig. 2) possessing a large absorption area plus unusual filtering efficiency. These disks are made of Feltex, an exclusive felt-like material used in most Staynew and Protectomotor air filters. The Feltex disks are carried on a tube composed of an inner liner of perforated metal covered with a fine bronze wire mesh screen. This tube ("4", Fig. 2) helps to drain oil removed from the air to the bottom of the filter shell. ("6", Fig. 2).

The lower portion of the filter shell is easily removed for inspection or cleaning by simply loosening the nuts on the swing bolts ("8", Fig. 2). The filter may also be purchased with standard bolted head.

Additional construction details are the deflector cup ("2", Fig. 2), which precipitates most oil and other foreign matter to the sides of the shell by centrifugal force; intake pipe ("1", Fig. 2); outlet ("5", Fig. 2), and drain cock ("7", Fig. 2). Direction of air travel is indicated by arrows.

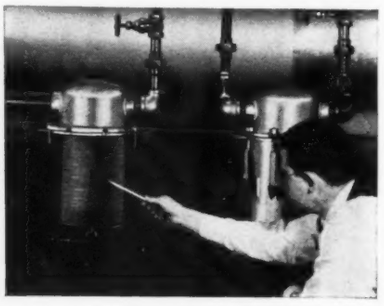
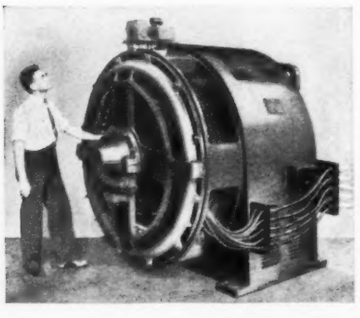


Fig. 3. Lower shell removed from one of two Model AAPHS filters

A wide range of pipe sizes and filter capacities is available.

Largest 60-Cycle BTA Motor

THE largest 60-cycle BTA motor ever built was recently completed by the General Electric Company for the Phillips Petroleum Company of Bartlesville, Oklahoma. This motor is rated 400 hp. and will develop constant torque over a 2 to 1 speed range of 410-205 r.p.m. It is of open construction, and has speed-changing brushes shifted by a pilot-motor-operated mechanism mounted at the top of the BTA frame.

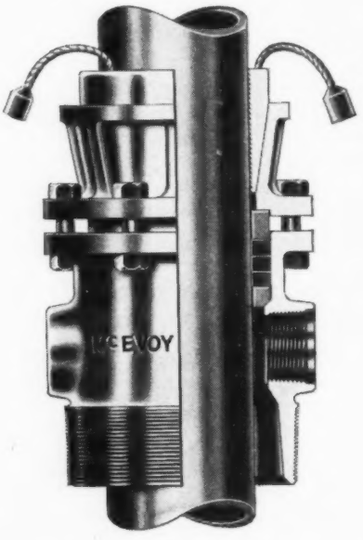


A contributing factor to the compact design of this motor is the fact that the collector rings are mounted on the shaft inside the drive-end shield.

General Electric began development of the BTA type motor as far back as 1913, and offered it for commercial use a few years later. Some of the advantageous operating characteristics of this type motor are smooth speed changes, good speed regulation from no load to full load, high efficiency at reduced speed points, simple control, and an adjustable a-c. drive in a single unit.

Low-Pressure Bradenhead Features Slip Suspension

A BRADENHEAD that brings the convenience of slip suspension to the low pressure field has been announced by the McEvoy Company, Houston, Texas. This head uses the same body and packing as the familiar Louisiana pattern bradenhead. The upper flange is provided with a slip bowl so slips may be used to support the casing at any point. This eliminates the necessity for accurate "nippling up" and assures proper load distribution, the manufacturer asserts.



Split gland rings are provided to simplify assembly. The entire head is simple and rugged and the cost is said to be exceptionally low. Known as the McEvoy Type SSA Bradenhead, it is available in all sizes for low- and medium-pressure wells.

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